HANDBOOK OF TECHNICAL INSTRUCTION FOR WIRELESS TELEGRAPHISTS


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Handbook of Technical Instruction for Wireless Telegraphists

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of
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for
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BY

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INTRODUCTION.

Owing to the rapidly increasing demand for wireless telegraphists and to the necessity for their acquiring a certain standard of efficiency in compliance with Regulations set up by an International Body, it has become necessary to introduce a Handbook for the instruction of operators.

The ordinary land telegraphist has usually a very hazy idea of the nature of the forces governing the working of his instruments. He knows that they depend for their action upon electricity, but beyond that he is able to explain very little on the subject.

It can readily be seen that the wireless telegraphist at sea must have a much more comprehensive knowledge of the apparatus than the land telegraphist, as he cannot depend upon linesmen or engineers to repair any faults which may occur, and, in fact, is usually absolutely responsible for the efficient working of his station. As the ranks of wireless operators are usually recruited from some branch of land working, it is necessary for the men to receive additional tuition. This will be the excuse for the introduction of a great deal of elementary matter which has appeared in multitudinous text-books.

The author wishes to thank Mr. H. Dobell, Superintendent of Instruction to Marconi's Wireless Telegraph Co., for his many suggestions and his careful reading and correction of the proof matter.

J. C. Hawkhead.

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CHAPTER I.

Preliminary Considerations.

Electricity, derivation of—Production by friction—Coulomb—Potential—Electro-motive force (E.M.F.)—Volt—Ampère—Conductors—Insulators—Resistance—Ohm—Current electricity—Circuit.

An operator with only a "tapping" acquaintance with his instruments knows that these depend for their action upon electricity. The word *electricity* derives its origin from the Greek word "elektron," meaning "amber."

Several hundred years ago it was discovered by scientists that a piece of amber rubbed with silk acquired certain properties. It was found that it acquired temporarily the power of attracting certain light bodies, such as small pieces of paper, feathers, straws, etc.

Other substances were found to be similarly affected by friction. Such bodies were then said to be electrified, or were said to be charged with electricity. It is found that the forces of attraction exerted by such electrified or charged bodies vary with the amount of electrification present. Assuming then that electricity has physical magnitude, it must be capable of measurement; hence the necessity of a standard unit. As the "foot" and "gallon" are units for linear and liquid measurement, so the "coulomb" is the unit of electric quantity. Thus a statement that a certain body is charged with, say, 20 coulombs of electricity, implies something similar to a statement that a tank contains 20 gallons of liquid.

The electricity thus produced by friction is in a stationary or non-moving state, being confined to the bodies between which the friction has been taking place.

The electricity used for telegraph purposes is a different type, being continuously in motion; and before we can realise the idea of such motion it is necessary to consider another property possessed by this electricity. In order to transfer heat from one body to another, say from A to B, the temperature of A in the first case must be higher

than that of B. Similarly, if a stream of water is to flow from one point to another, the pressure at the point from which it flows must be greater than the pressure at the point to which it flows.

The property of electricity corresponding to temperature and to pressure is known as "potential." Thus electricity will pass from any point at a certain potential to any point at a lower potential provided that a suitable path exists between the two points. It will be readily seen that the greater the difference of the potential between two points the greater will be the amount of electricity transferred during any period along the path, just as the amount of water transferred during a certain period depends upon the pressure exerted.

The difference of potential, therefore, determines, in addition to the direction of the motion of electricity, the amount of such motion. Hence potential difference is called electro-motive force, or E.M.F. For practical purposes the difference of potential must be measurable and the necessity for a unit arises. The name of this unit is the "volt."

If the student can imagine himself sitting on the bank of a river he will appreciate the fact that more water would flow past him in one hour than would pass him in one minute. Also that in any given time a greater quantity of water would pass if the rate of flow were 10 miles an hour than if it were 5 miles per hour.

The passage of electricity along a suitable path takes place in a certain time. Consequently, when we are dealing with electricity in motion, it is necessary to take time into account. When one coulomb of electricity (that is to say, unit quantity) passes a certain point in one second (that is to say, in unit time), unit current is said to flow. The unit of current is called the "ampère." So that current or ampèrage may be compared with velocity of flow.

We have stated above that the transference of electricity will only take place provided that a suitable path exists. Some materials are better adapted to the passage of electricity through them than others. Those materials through which the electricity passes with great facility are known as "conductors," and those through which the

electricity passes only under great pressure, or in some cases apparently not at all, are called "insulators."

There is no such thing as a perfect insulator, and no such thing as a perfect conductor, but more will be explained on that subject later.

Whenever we make an effort against any force we do work and are conscious of having expended energy. Whenever electricity passes along a conductor it does work, for it has to overcome a certain amount of resistance.

As the resistance offered by different materials to the passage of electricity through them varies in accordance with their dimensions as well as in accordance with the different material, it is necessary to have a standard unit in order that measurements may be made. The unit of resistance is the "OHM." Just as the sign ″ is used to represent inches so the sign "ω" (the Greek letter Omega) is used to represent "OHM."

So far we have only considered one method of generating electricity, viz., the application of friction to certain bodies. This method only produces electricity in extremely small quantities, and in a form which is useless to us for practical purposes, namely, the "static," or stationary form. It has been stated that the electricity for telegraph purposes is electricity *in motion*, or current electricity.

The current electricity of the type with which we will deal first—continuous current—necessitates a complete path of conductors before it can exist. The complete path along which the current passes is called a "circuit."

Our attention will next be devoted to a study of the simpler methods of producing current electricity.

CHAPTER II.

PRIMARY CELLS.

Simple cell—Water analogy—Chemical action—Atom—Molecule—Element—Compound— Polarity—Kathode—Anode—Chemical equation—Polarisation, prevention of—Single fluid cell—Léclanché cell—Dry cell—Double fluid cell—Daniell cell, chemical action of—Saturated solution—Local action—Amalgamation.

IN the preceding chapter it was stated that a transference of electricity from one point to another along a conductor can only take place when a difference of potential or a difference of electrical pressure exists between these two points. Therefore, if we can devise some apparatus capable of producing potential difference, we shall satisfy the first requirements. This we find is a very easy matter, for, if two plates of different metals are immersed in acidulated water, we find that a difference of potential does exist, and if a suitable conducting path be made across the external portions of the plates, the conducting path will exhibit certain properties. It will be useful here to refer to the accompanying diagrams.

Fig. 1 represents the electrical circuit. A and B are plates of zinc and copper respectively, which can be placed at will in the vessel, C, containing water slightly acidu-

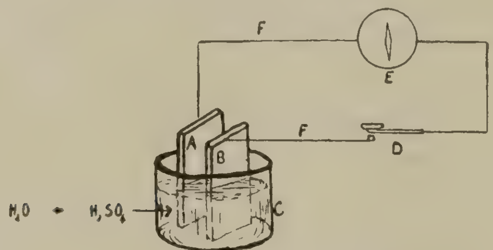


Fig. 1.—Simple Cell.

lated with sulphuric acid. Between the upper extremities of A and B a copper wire, FF (copper being a good con-

ductor) is joined. E is an instrument inserted in this copper wire for the purpose of detecting the passage of electricity. D is a key by means of which we can make or break the circuit.

In Fig. 2 a jar, J, containing water, is connected by means of a rubber tube, T, to the glass tube, G. This arrangement we will call the water circuit. It will readily be understood that when the level of the water in the jar and in the tube is the same no water can pass from jar to tube. If, however, the jar, J, be raised to a higher level, water will flow

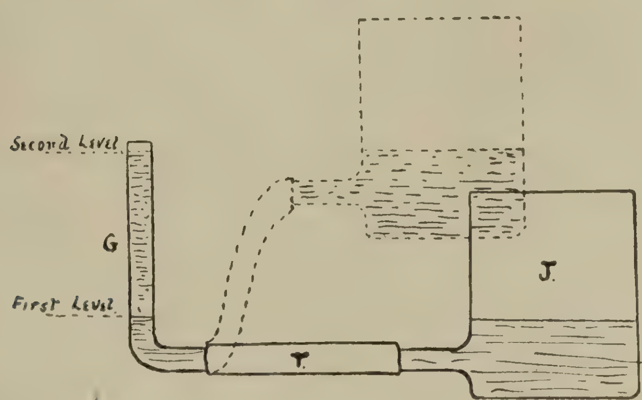


Fig. 2.—Hydraulic Analogy of Electric Circuit.

through the rubber tube into the tube, G. The action of the electric circuit is very similar. If the key, D, be depressed while the plates, A and B, are lifted out of the vessel, C, the instrument will not indicate a passage of any electricity. If, however, the plates be immersed in the liquid, a passage of electricity is at once indicated. Just as the raising of the vessel, J, produces a difference of water pressure between the two vessels, so the placing of the plates in the liquid produces a difference of electrical pressure between the plates. As the rubber tube offers a path for the passage of the water, so the copper wire affords a path for the passage of electricity. If a stopcock be inserted in the rubber tubing it would perform a similar function to that performed by the key in the electrical circuit.

"SIMPLE CELL."

Such an arrangement of unlike metals immersed in a vessel containing acidulated water is known as a cell. It is

found that when the circuit is complete bubbles of gas are given off from one of the plates and the other plate is gradually eaten away. Let us consider what action takes place in the particular cell just described. The action is of a chemical nature, and a few words of explanation are necessary for the proper understanding of chemical action. A substance which cannot be subdivided is called an element. Thus, copper, which cannot be split up into anything else but copper, is an element. Copper can, however, be combined with other elements. Such a combination is known as a compound. Elements and compounds are represented symbolically. The smallest portion of an element which can take part in chemical action is called an "atom." The smallest quantity of a compound is called a "molecule." Thus, Cu represents one atom of copper.

Copper can be combined with sulphur and oxygen to form a compound called copper sulphate.

A molecule of this compound would be represented by $CuSO_4$, implying that it contains one atom of copper, one atom of sulphur, and four atoms of oxygen.

Whenever chemical action takes place a rearrangement of the atoms of the different elements is the result. It is easily seen, therefore, that chemical action can be represented by means of an equation.

The simple cell just described is known as a single-fluid cell on account of the fact that only one liquid is used. Its action is presumed to be as follows:—

The liquid (sulphuric acid) is decomposed—that is to say, it is split up into its component parts. One of these is a combination of oxygen and sulphur and another is hydrogen. The oxygen-sulphur combination (or "SO_4 radical," as it is called) attacks the zinc and combines with it to form zinc sulphate, and the hydrogen is evolved at the copper plate in the form of bubbles. The potential of the chemically attacked zinc plate is higher than that of the copper plate. A transference of electricity therefore takes place from the zinc to the copper through the liquid in the cell, returning from the copper through the external path back to the zinc.

Because the chemically attacked zinc is at a higher potential than the copper, it is said to be positive with respect to the latter. The zinc and copper plates are known

as the "elements" of the cell, and are respectively the positive and negative elements. The external portions of the elements are supplied with terminals, or binding-screws, and are known as the " poles." As the current flows externally from the copper to the zinc the former is called the positive pole and the latter the negative pole. Thus great care must be taken not to confuse the poles and the elements. The positive pole is also called the kathode, and the negative pole the anode, these words denoting the exit and entrance respectively of the current with regard to the cell. The following diagram will sufficiently illustrate this form of simple cell. (Fig. 3.)

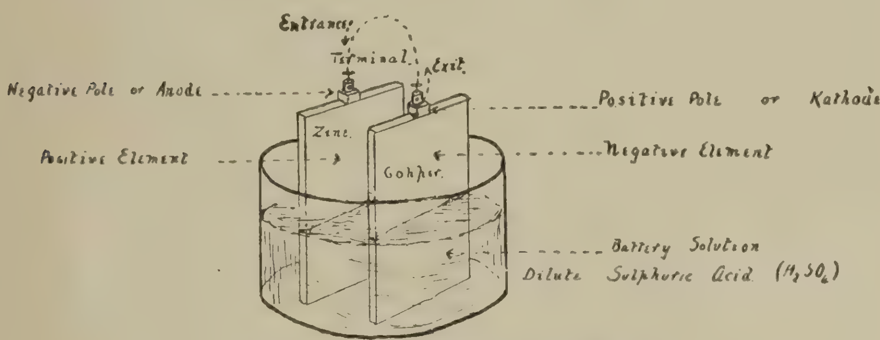


Fig. 3.—Composition of Simple Cell.

The chemical action which takes place can be represented by the following equation:—

Zinc + Suphuric Acid = Zinc Sulphate + Hydrogen,

or, symbolically—

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

Other substances than copper and zinc may be used as elements, such as platinum and zinc, carbon and zinc, etc. The positive element is that which is most readily attacked by the acid.

Polarisation.—It has been stated that bubbles of hydrogen are evolved at the copper plate. Some of this hydrogen rises to the surface of the liquid and escapes into the air. A part of it, however, adheres to the copper plate, and after the cell has been working for a short space of time the plate becomes almost covered with a thin film of hydrogen. The hydrogen is found to have a much higher potential with respect to the zinc than the copper has, and the consequence is, of course, that the difference of poten-

tial between the two plates is decreased. Hydrogen also offers a greater resistance to the passage of electricity. It is seen, therefore, that a cell of this type very rapidly loses its efficiency. When the copper plate has become covered with the film of hydrogen the cell is said to be "polarised."

The potential of the zinc element is 1·86 volts and that of the copper element ·81 volts. The effective difference of potential or E.M.F. is therefore expressed by $1{\cdot}86 - {\cdot}81 = 1{\cdot}05$ volts. Now, the potential of hydrogen is about 1·3 volts. The difference of potential at polarisation therefore becomes $1{\cdot}86 - 1{\cdot}3 = {\cdot}56$ volts. The polarisation of a single-fluid cell can be reduced by such devices as roughening the surface of the negative element or by keeping it in motion. Neither of these devices, however, are much used in practice. To get over this trouble another type of cell is designed in which provision is made for the combination of the hydrogen with other substances immediately it is produced.

The Léclanché Cell.—This is perhaps the best known of this type. It usually consists of a square glass jar containing a saturated solution of ammonium chloride, which is known commercially as sal-ammoniac. A porous pot, containing a carbon rod in the centre packed round with manganese dioxide (MnO_2) and crushed carbon, is placed inside the glass jar. The top of the porous pot is sealed

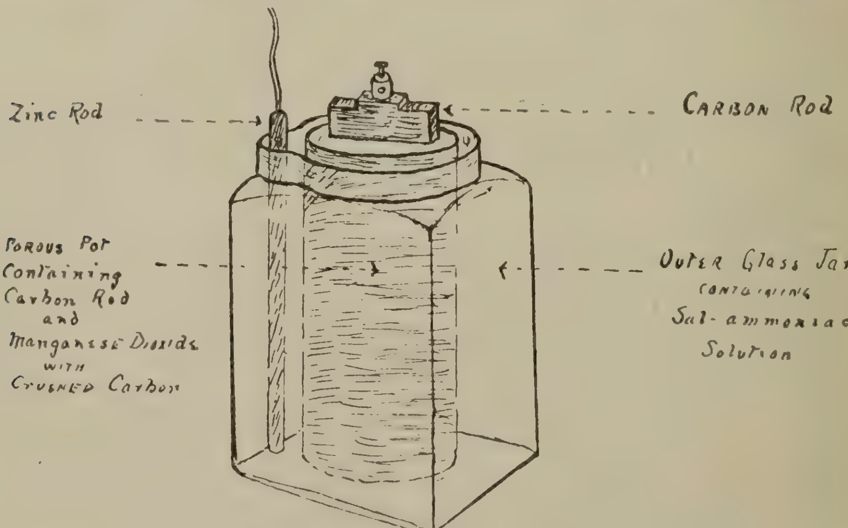


Fig. 4.—Léclanché Cell.

with pitch, a small hole being left for the escape of the gas produced by chemical action. The carbon is the negative element. A zinc rod is also placed in the sal-ammoniac solution, thus providing the positive element. The porous pot allows the solution to make good contact with the crushed carbon and manganese dioxide. (Fig. 4.)

The action of this cell is as follows:—The sal-ammoniac attacks the zinc, forming a double chloride of zinc and ammonium. Hydrogen is liberated, which combines with a certain amount of oxygen, supplied by the manganese dioxide, to form water, thus preventing the polarisation of the carbon or negative element.

The Dry Cell (Fig. 5).—A very common type of primary cell, and almost the only type with which the average wireless telegraphist will come in contact, is known as the dry

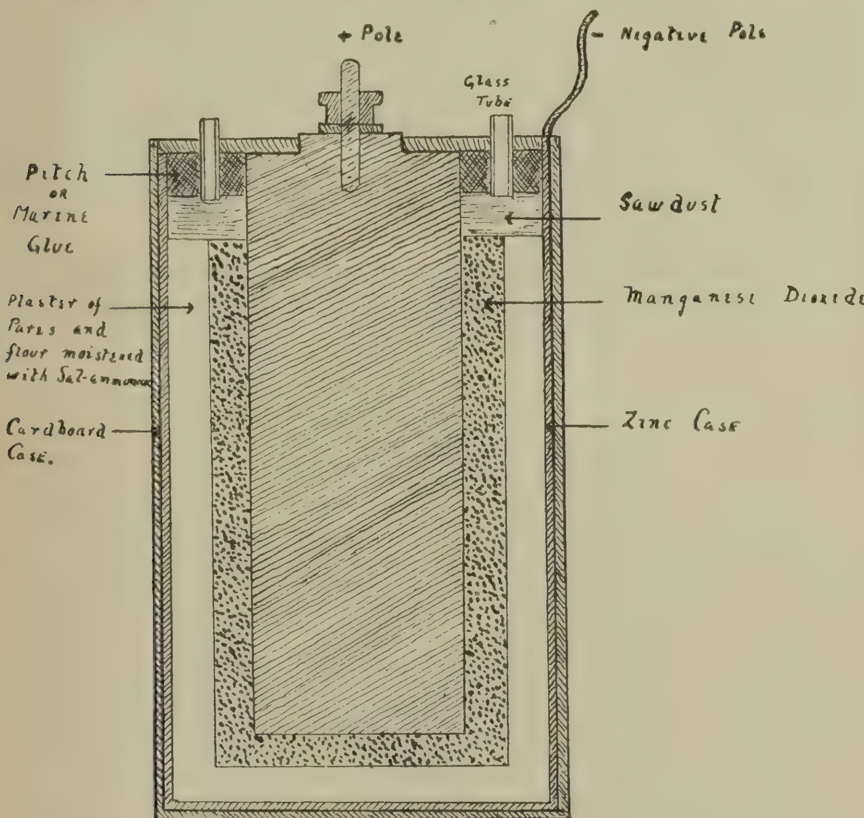


Fig. 5.—Section of Dry Cell.

cell. The action of this cell is precisely the same as that of the "Léclanché." It possesses the advantages, however, of cleanliness and portability. This cell consists of a zinc

case which acts as a container and at the same time as the positive element. It is protected and insulated on the outside by means of a cardboard sheath. In the centre is fixed a carbon rod, carrying a terminal at its upper extremity, which is surrounded by a mixture of manganese dioxide and graphite or crushed carbon. Between this mixture and the zinc container a lining of plaster of Paris and flour, moistened with a saturated solution of sal-ammoniac, is placed. The top is filled in with a padding of cotton-wool or sawdust and sealed with pitch or marine glue, through which two small glass tubes run to afford an outlet for the gases produced by chemical action.

This cell cannot be used for any protracted period of time without polarisation taking place to some extent. The manganese dioxide only liberates oxygen—which, it will be remembered, combines with the liberated hydrogen to form water—slowly, and consequently after a certain time, more hydrogen is liberated than can be dealt with. If left for a little while, however, the cell recovers itself. It will be understood, therefore, that this type is very useful when intermittent service is required, as in the case of electric bells, etc.

The two cells described are of the single electrolyte type. Although it is very improbable that a wireless operator

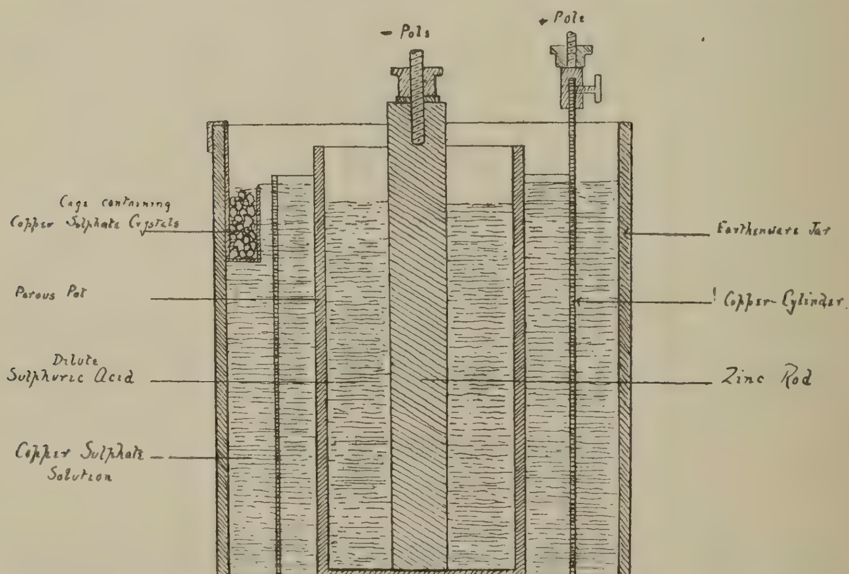


Fig. 6.— Section of Daniell Cell.

will have dealings with any other type of primary cell, a description of a cell of the double-fluid type may be useful.

The Daniell Cell (Fig 6).—This cell is usually made up of an earthenware container with a porous pot inside it. The negative element is a copper cylinder, which rests in a saturated solution of copper sulphate, placed in the outer jar, and the positive element is a rod of zinc immersed in a dilute solution of sulphuric acid contained in the porous pot.

The action is as follows:—The zinc is attacked by the acid and gradually eaten away, zinc sulphate ($ZnSO_4$) being formed in solution. Hydrogen (H) is evolved at the copper plate and combines with the SO_4 group contained in the copper sulphate ($CuSO_4$) to produce sulphuric acid (H_2SO_4), which percolates through the porous pot and maintains the strength of the original acid. It will be seen that when the SO_4 group is taken from the copper sulphate ($CuSO_4$), copper should be left. As a matter of fact pure metallic copper is deposited on the copper plate in the form of a black powder.

The following equations illustrate the action:—

Before the circuit is complete.

Outer Jar.

Copper, Copper, Copper Sulphate.

$Cu \quad Cu \quad CuSO_4$

Porous Pot.

Sulphuric Acid, Zinc.

$H_2SO_4 \quad Zn$

After circuit is complete.

Porous Pot—Sulph. Acid + Zinc = Zinc Sulphate + Hydrogen.

$$H_2SO_4 + Zn = ZnSO_4 + H_2$$

Outer Jar—The liberated H_2 passes to the outer jar where:—Copper Sulph. + Copper Sulph. + Copper + Hydrogen = Sulph. Acid + Copper + Copper Sulphate.

$$CuSO_4 + CuSO_4 + 2Cu + H_2 = H_2SO_4 + 3Cu + CuSO_4$$

Saturated Solution.—In the descriptions of the Léclanché and Daniell cells use is made of the expression "saturated solution."

By a solution we understand a liquid formed by dissolving some substance in water. A saturated solution is a solution containing as much of the substance as it is

possible to dissolve. When copper sulphate is added to water it will dissolve until a certain point is reached, after which any additional copper sulphate remains at the bottom of the vessel containing the solution.

In the case of the "Daniell" cell, it is seen that the copper sulphate is being continuously decomposed by the liberated hydrogen. In order to maintain the solution in the outer jar at a point of saturation, it is usual to provide a cage in which pure copper sulphate crystals are placed, which will gradually dissolve to replace that which has been split up during the production of pure copper and sulphuric acid.

Local Action.—In each of the cells described it is stated that the zinc element is gradually eaten away. This action only takes place when the circuit is complete, but under certain conditions the eating away will be excessive. Commercial zinc invariably contains certain impurities, usually being small quantities of such materials as copper,

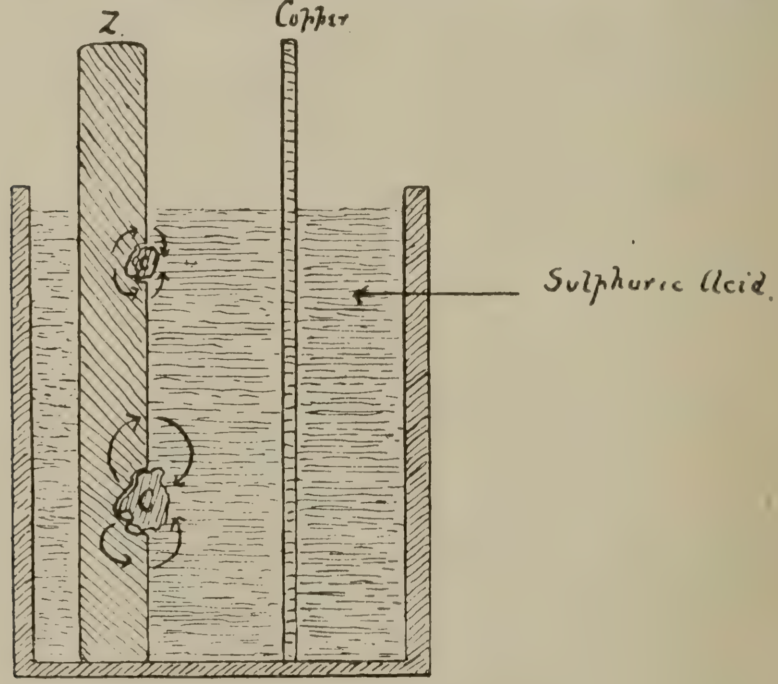


Fig. 7.—Local Action.

arsenic, lead, etc. When such impurities are on the surface of the zinc rod used in a cell the following action takes place. In the accompanying figure (Fig. 7) Z represents

the zinc rod and C a particle of copper impurity greatly magnified. When such a rod is immersed in dilute acid a local miniature cell is formed, the zinc being the positive element and the copper impurity the negative, the small space between being filled with dilute acid. Thus a zinc rod containing many impurities would be rapidly eaten away even on an open circuit.

Amalgamation.—Most metals very easily form an alloy with mercury, such alloys being called "amalgams," and the process producing them being known as "amalgamation." A zinc rod may be amalgamated as follows:—

Using a greasy cloth to prevent burning of the fingers, the zinc rod is first cleaned with dilute hydrochloric or sulphuric acid. Mercury is then rubbed over the rod until it presents a bright and shiny surface. When such an amalgamated zinc rod is used in a cell mercury fills the space between the zinc and the impurities, and the conditions for local action are thus removed.

In the case of the "Daniell" cell local action is avoided in a different way. It will be remembered that zinc sulphate is spontaneously formed in the action of the cell. When zinc sulphate takes the place of the sulphuric acid local action is avoided. If, therefore, the action be allowed to take place for some time before the cell is actually required it becomes unnecessary to use anything more than water in the zinc cell at the commencement.

There are many other types of cells, such as the "Bichromate," "Bunsen," "Grove," etc., but as a knowledge of these types is not necessary, no description is given here.

CHAPTER III.

Accumulators.

Electrolysis—Electrolyte—Electrodes—Ions—Simple accumulator or secondary cell—Commercial accumulator—Plates, positive and negative—Containers—Separators—Theory of specific gravity—Hydrometer—Hicks's suction hydrometer—Charging—Test for polarity of charging mains—Gassing—Discharging—Sulphating—Buckling—Local action—Evaporation—Growths—Management of accumulators—Treatment when not in use.

Electrolysis.—Just as chemical action can be utilised for setting electricity in motion, as described in the previous chapter, so electricity in motion is capable of setting up chemical action. When a current is sent through certain liquids, they are split up into their component parts. If a current is sent through water, which is a combination of the gaseous elements hydrogen and oxygen represented by the formula H_2O, the water is split up into these two gases. Thus if C represents some form of primary cell, and V is a vessel containing water, when the ends

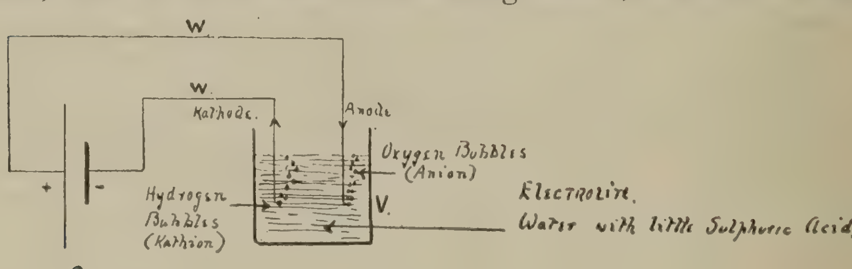


Fig. 8.—Electrolytic Cell.

of the wire W are placed in the water, bubbles of gas arise at either end of the wire, which on examination prove to be bubbles of oxygen and hydrogen respectively. If a little sulphuric acid be added to the water the action is increased, as the liquid then offers less resistance to the passage of the current—indeed, perfectly pure water is a non-conductor.

The process which decomposes the liquid by the passage of a current is called "electrolysis," the liquid being known as the "electrolyte," and the ends of the conducting wires "electrodes."

The whole arrangement of the vessel, electrolyte and electrodes is known as an electrolytic cell, and the electrode at which the current enters is called the "anode," the one at which it leaves being called the "kathode."

The substances into which the electrolyte is split up are called "ions," and as the hydrogen appears at the kathode it is called the "kathion," the oxygen being called the "anion."

During the electrolysis of any solution which results in the formation of hydrogen or any of the metals, the latter travel with the current, and as this passes inside the cell from the anode or leading-in electrode to the kathode, hydrogen and the metals are deposited on the leading-out electrode or kathode.

The formula of water has been given as H_2O, implying two atoms of hydrogen to one of oxygen in every molecule. Experimentally it is found that two volumes of hydrogen are given off to one of oxygen.

Here, therefore, we have a simple method of finding out the positive and negative poles of a cell or other source of current, for, if the source of supply be connected up to a simple electrolytic cell, gas will be given off more freely at the electrode in connection with the negative pole.

SIMPLE ACCUMULATOR.—If lead plates are attached to the ends of the conducting wire immersed in the dilute acid several changes are found to take place when the current is passed through. The strength of the acid is affected, and changes take place in the composition at the surfaces of the lead plates. These changes will be discussed more fully later.

If the primary cell is now disconnected from the electrodes, and an external circuit closed upon these, a current is found to flow and gradually the plates are found to approach their original state and the acid its original strength.

When a certain point has been reached the cell is found to be incapable of producing further current. To summarise the above we find that by passing a current through

the electrolyte and electrodes we have produced a type of cell capable in turn of producing a limited amount of current. Such an arrangement is therefore called an "accumulator," storage battery or secondary cell. The names "accumulator" and "storage battery" are really misnomers, as they do not store up a supply of electricity; they do, however, store up some of the energy supplied to them. What really happens is that the electricity supplied produces chemical action, and when the supply is cut off and an external circuit joined across the electrodes an opposite chemical action in the secondary cell sets electricity in motion. The chemical action in the first case has converted one of the lead plates into lead peroxide (PbO_2), and we thus have two dissimilar plates immersed in dilute acid as in the case of the simple cell.

Commercial Accumulators.—A simple accumulator of the type just mentioned would be of very little use for practical purposes, and considerable modifications are necessary. It will be readily understood that the greater the surface presented to the electrolyte the greater will be the action. For this reason the practical accumulator is usually made up of several positive and negative plates grouped as in the accompanying diagram (Fig. 9). There

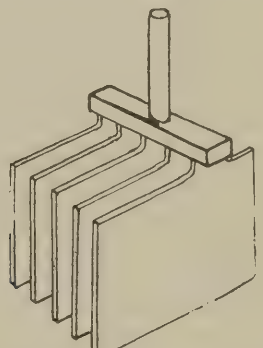


Fig. 9.—Group of Accumulator Plates.

is always one more negative than positive plate in order that both sides of every positive plate may be acted upon.

The positive plate consists of a frame made of lead strengthened with antimony, containing a number of holes into which a paste made of red lead and sulphuric acid is pressed.

The negative plate is made of chemically pure lead.

Each cell consists of one set of positive and one set of negative plates fixed in a container, which for use at sea usually consists of a lead-lined teak box. As it is extremely important that the opposite plates do not touch at any point, separators are introduced which usually take the form of glass rods, perforated ebonite or celluloid sheet, or thin wooden boards of specially prepared wood. In the type of accumulator used at sea the separators are of the last-mentioned type, and an idea of their appearance will be better gathered from the accompanying diagram (Fig. 10).

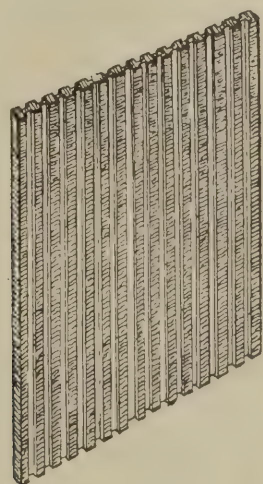


Fig. 10.—Wooden Separator for Accumulator.

It will be seen that the boards are grooved on either side, this being to allow the acid to have better access to the surface of the plates. The plates when packed for transport are generally separated by distance-pieces of ordinary wood. These must be removed without fail and replaced by the proper separators before putting in the electrolyte. The edges of the two kinds of plates are prevented from making contact along the lead lining, by means of ebonite sheets at the sides, and by being supported on an insulated rack set in the bottom of the container, a diagram of which is given (Fig. 11).

The Action of the Accumulator.—When such accumulators are received from the manufacturer they invariably require a long initial charge. That is to say, a current from a dynamo or primary battery must be sent through them for at least thirty hours. This current produces

chemical action, which results in the negative plate being composed of pure lead in a spongy state, while the positive plate is composed almost entirely of lead peroxide.

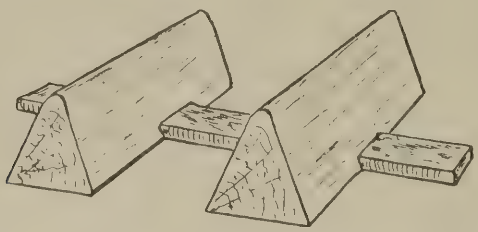


Fig. 11.—Insulating Stand for Accumulator Plates.

After a normal discharge—that is to say, after as much current has been taken from the accumulator as is consistent with the well-being of the plates—about half the lead in the negative plate and half the lead peroxide in the positive plate is converted into lead sulphate. At the same time the strength of the acid drops, as part of it is taken up in the formation of this sulphate. The strength of the acid is therefore a good indication of the condition of the cell.

When charging, the action is exactly the reverse, the plates are once more converted into their original state and the acid rises to its original strength, provided the accumulators are in good condition.

The Hydrometer.—An instrument called a hydrometer is used for testing the specific gravity of the acid. It indicates the proportion of the weight of a given volume of the liquid to the weight of an equal volume of water at the same temperature. Different types of accumulators require acid of slightly varying strength. That made by the Chloride Accumulator Company requires acid of an initial specific gravity of 1·215. That is to say, if one cubic centimetre of water weighs one gramme, one cubic centimetre of this acid weighs 1·215 grammes.

There are several different types of hydrometers. When a body floats in any liquid we know that the weight of the liquid displaced is equal to the weight of the body. A simple hydrometer may therefore be made as follows:—Into a tube, A (Fig. 12) a sufficient quantity of lead shot is placed—held in position by paraffin wax—to make

it float in water up to, say, the level, B. If this water be at a temperature of 4 degrees centigrade this level represents a specific gravity of 1. Different standard solutions of known specific gravities may then be taken, and it will be found that the tube will float in them so that more or less of it will be immersed. Thus in alcohol and certain oils the tube would sink deeper because their specific gravities are less than that of water. In a solution of salt or sulphuric acid the tube would be less deeply immersed, indicating a greater specific gravity. If then, as stated above, certain standard solutions be taken, a graduated scale can very easily be marked on the outside

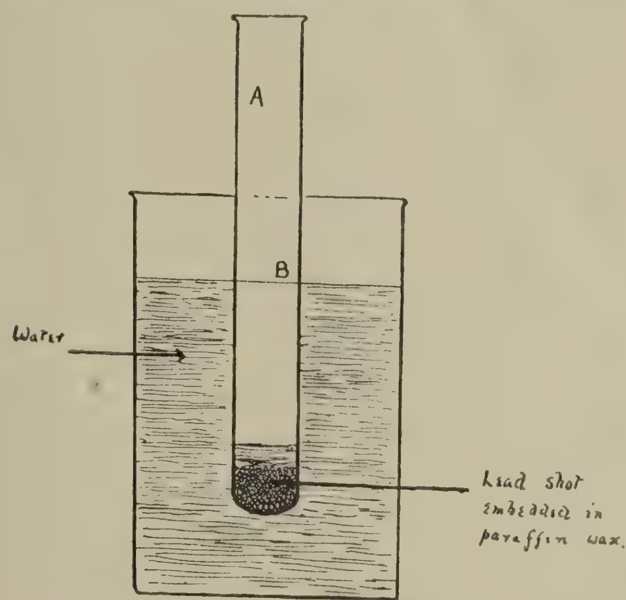


Fig. 12.—Construction of Hydrometer.

of the tube. For taking the specific gravity of the acid in accumulators this type is not very convenient, as the plates usually occupy all the space in the container. A form of hydrometer known as "Hicks's Suction Hydrometer" is therefore very often employed. This consists of a glass tube, as shown in Fig. 13, fitted with a rubber teat very similar to the ordinary fountain pen filler. Inside this tube different coloured glass beads are contained, each of which would float in a liquid of certain specific gravity. A table is supplied with the instrument giving the specific gravities corresponding to the different beads. In order to test the specific gravity of the acid in

an accumulator, it is only necessary to insert the end of the tube in the liquid and to squeeze and release the teat, which excludes the air and allows a little of the acid to

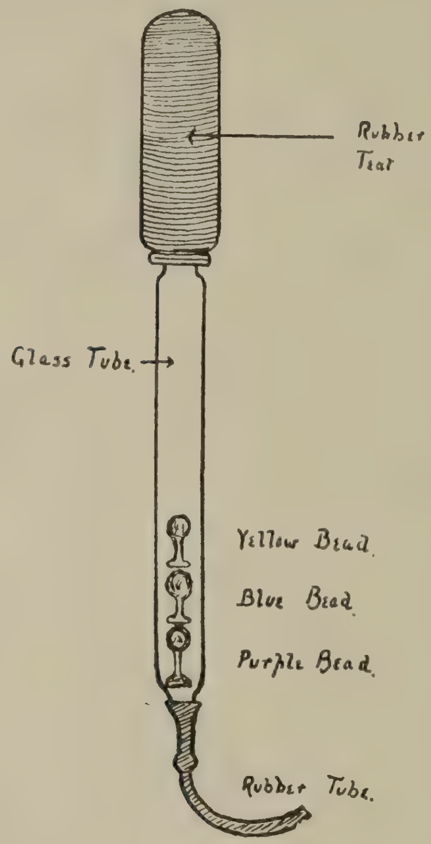


Fig. 13.—Hicks's Suction Hydrometer.

fill the tube. The reading corresponding to the particular bead which floats nearest the centre of the tube gives the specific gravity of the acid. In the type supplied to operators the specific gravities indicated are:—

Yellow..................	1·170
Blue.....................	1·185
Purple..................	1·200

Charging.—As previously stated, new cells require a long initial charge, and great care must be taken that certain conditions are satisfied before commencing. The positive pole of the source of supply of the charging current must be connected to the positive pole of the

accumulator battery, and the negative pole to the negative. A method of distinguishing the polarity of the charging loads has been mentioned under the heading of "Electrolysis," when it is stated that gas will be more freely liberated from the electrode in connection with the negative pole of the source of supply.

In order to test properly for polarity two small pieces of lead should be connected to the ends of the two supply mains, these pieces of lead forming the electrodes of the simple electrolytic cell; a resistance such as a lamp being included in the circuit if the voltage is high. It would be seen that the electrode from which gas was being evolved less freely would turn brown, due to the formation of lead peroxide. As a rule, lead-covered cable is used in a wireless installation, and strips of the lead sheathing may be conveniently used for this test. Another simple way of testing is by pressing the end of the two leads on to a piece of damp blue print paper. The paper under the negative lead turns white.

The positive pole of the accumulator can be recognised as follows:—It is always of a chocolate-brown colour, and the paste can readily be recognised in the lead frame. All the positive plates in a cell are joined together by means of a lead strip, which is usually painted red, and the pole piece is generally insulated from the cover of the container by means of a piece of red rubber tubing. In the type of accumulator supplied to ships the pole piece is of round section, and the upper extremity appears as a circle (Fig. 14).

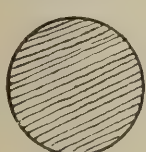


Fig. 14.—End View of Positive Pole.

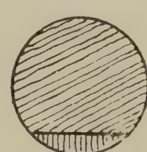


Fig. 15.—End View of Negative Pole.

All the negative plates are similarly joined together by means of a lead strip or bar, but in this case it is painted black, and the insulating tube is of black rubber. The pole piece is generally filed in such a manner that its upper extremity appears as in Fig. 15.

The outside of the container and cover are also marked with the following signs:—

Positive + Negative −

When building up an accumulator cell great care must be taken that the plates are so placed in the container that the poles coincide with these marks. Before making the actual connections between the dynamo and the accumulator battery, it is necessary to see that the former is delivering current at a greater pressure than that which the battery can produce. Otherwise the battery would discharge itself through the dynamo, as its pressure is acting in an opposite direction to that of the charging current.

Assuming then that the charging current at our disposal is of suitable dimensions (its voltage should be at least 10 per cent. higher than that of the battery), the acid is put into the cells until it rises about half an inch above the level of the top edges of the plates, and the connections are made. The reason that the adding of the acid is left until all else is ready for the commencement of charging is that it would needlessly attack the lead plates if added earlier.

Suitable measuring instruments are used in the circuit, but these will be described later when dealing with a particular circuit actually used in a Standard Marconi Installation. These instruments indicate when the battery is fully charged or discharged.

An instrument called a voltmeter indicates the potential difference, but in order that this reading may be a true indication of the condition of the cell it must be taken when the cell is delivering current. When the cell is not delivering current it usually shows a pressure of two volts, which does not depend much upon the extent to which the cell has been charged or discharged. If a cell gives a pressure much below two volts when no current is passing it is usually in a very bad state.

As the process of charging continues, it is found that the specific gravity of the acid slowly rises. The voltage also rises, slowly at first and then more rapidly, until the difference of pressure between the poles of each cell is about 2·6 volts.

Now the specific gravity of the acid rises most rapidly in the parts adjacent to the plates. The difference of pressure depends to a great extent on the specific gravity. When the charging is stopped the specific gravity of the acid becomes uniform, and that of the part adjacent to the plates is slightly lowered, with a resulting decrease in pressure, and it is found that shortly after cutting off the charging current from a fully charged cell its potential difference drops to about 2·1 volts. If the voltage of a cell fails to rise properly towards the end of the charge it is an indication that it is in a bad state.

Gassing.—A cell is fully charged when the specific gravity of the acid ceases to increase. After this point is reached the charging current is only being used to decompose the water in the cell into hydrogen and oxygen. Bubbles of these gases then rise to the surface. Usually there is a sufficient number of these small bubbles at the end of a charge to give the acid quite a milky appearance. The current required for charging accumulators varies in different makes, and of course the supply has to be regulated in accordance with the makers' instructions. When the correct charging current is used and the cells are gassing freely at both positive and negative plates, the current should be reduced to one-half and charging be continued until they once more begin to gas. At this point charging should be stopped.

Discharging.—The value of the current taken from the accumulators must not exceed the maximum specified by the makers. As current is taken away the reverse of the charging process takes place. The specific gravity and the voltage slowly drop. This drop must not be allowed to fall below certain limits. The voltage of a cell on a closed circuit should never be allowed to fall below 1·85 and the specific gravity below 1·170.

Faults—Sulphating.—The most common fault is known as sulphating. When the cell is being discharged it has been stated that lead sulphate has been formed on both plates. This lead sulphate is in such a form that it is easily soluble during the charging process under normal conditions. When a cell is discharged below the limits given, or even when a discharged cell which has not been allowed to discharge below these limits is left inactive

for any length of time, the sulphate appears to work out to the surface of the plates in the form of crystals, which are almost insoluble and very difficult to remove. This sulphate is a very poor conductor, and offers great resistance to the passage of the current, and consequently the efficiency of the cell is very much impaired.

A sulphating cell may be easily detected because the specific gravity of the acid at the end of a charge will be less than it was at the end of the first charge. This is because the plates have not liberated as much acid during charge as they took up during discharge, as part of the acid has been used to form the insoluble sulphate. The remedy for this is extra charging. The faulty cell must be cut out of the battery after a charge and replaced during the next charge. When a cell is very badly sulphated the sulphate is seen adhering to the plates, and it is extremely difficult to remove. In fact, it is often found cheaper to supply new plates.

Buckling.—When lead or lead peroxide is converted into lead sulphate, the latter has a much larger volume than either of the former materials. Actually the volume of lead sulphate is about twice the volume of a corresponding quantity of lead peroxide and about three times the volume of a corresponding quantity of metallic lead. When, therefore, an accumulator is discharging, the paste in the positive plates and the lead in the negative plates gradually expand. This expansion has a great tendency to cause buckling of the plates, and is largely responsible for the dropping in voltage during discharge. As the material expands it closes up the pores, thus preventing the acid from coming into contact with the whole amount of active material. This expansion of active material, together with violent gassing and local action—which is an action similar to that described in connection with the primary cell—results eventually in the disintegration of the plates.

In the type of accumulator supplied with wooden separators the buckling and disintegration are to a certain extent prevented.

If any foreign conducting matter is allowed to fall between the opposite plates the resistance at this point is lessened, and unequal action takes place with unequal

expansion of different parts of the same plates, and a consequent twisting or buckling ensues.

Local Action.—Another type of local action than that already explained takes place in an accumulator. This takes place between the lead of the positive plate and the lead peroxide with which it is coated. This action is lessened more or less by the coating of lead sulphate which the action itself causes to be formed on the lead.

In order to reduce local action as far as possible great care must be taken that the electrolyte is as pure as possible when it is first made up, and that no metallic impurities are allowed to fall into the cell when in use.

Evaporation.—The liquid in the cell gradually shrinks in volume. This shrinkage is usually due to evaporation of water, and must be compensated for by the addition of pure distilled water. Some loss also takes place on account of the splashing caused by gassing, but splash boards are usually supplied which fit closely over the top edges of the plates, and this loss is very small. Should any of the acid be accidentally spilled dilute acid of the original specific gravity must be added.

Growths on Plates.—If a flake of paste from the positive plate falls on to the negative plate it will discharge itself as well as that part of the plate on which it has fallen. During the next charge this projecting flake will be converted into spongy metallic lead, and during the ordinary working of the cell will tend to grow larger and larger, and if not removed may finally short circuit the cell by touching the opposing plate.

The Management of Accumulators.—Cells should not be discharged at a greater rate than that specified by the makers, nor should the discharge be continued beyond the point at which the voltage during discharge has dropped to the limit mentioned—*i.e.*, 1·85 volts.

Cells should not be allowed to remain discharged longer than necessary, and when they are charged they should be fully charged at a rate not exceeding that specified; and prolonged or violent gassing should be avoided.

A watch should be kept on the specific gravity of the acid in each cell when the charge is apparently complete. If it is not up to standard strength in any cell that cell

should be cut out of circuit during discharge and replaced during the next charge in order to remove any insoluble sulphate by extra charging. The action of sulphating is also indicated by an abnormal dropping of the voltage during discharge.

The level of the electrolyte must be kept above the tops of the plates as explained.

The cells should be regularly inspected to see if there are any flakes or growths in such a position as to be liable to short-circuit the cell. If found, they should be scraped off.

Treatment of Cells when Not in Use.—When a battery is to be left for any considerable time in an inactive state special steps must be taken to prevent deterioration. If it is to be left for only a month or so it is only necessary to give it an extra charge after seeing that each cell is in a good condition. Should it be left for a longer period than this the following steps should be taken.

The battery should be given an extra charge, and after care has been taken that every cell is in a good condition, the acid should be poured off and the plates, where possible, placed to soak in pure distilled water for about twenty-four hours. They should then be taken out of the water and allowed to dry, afterwards being replaced in the dry containers until required for further use. On being brought into active service again they must be given a long charge, as it is necessary to remove certain salts from the negative plate which are formed by oxidation due to exposure to the air.

In cases where it is possible to give the battery a prolonged charge about once a month, it is quite unnecessary to remove the acid, etc., as such periodic charging will keep it in a good condition for an indefinite time.

CHAPTER IV.

CURRENT ELECTRICITY: ITS LAWS AND UNITS.

Relation between current, E.M.F., and resistance—Ohm's law—Specific resistance—C.G.S. units—Series resistance—Parallel resistance—Arrangement of cells—Batteries—Arrangement for maximum current from given number of cells—Potential slope—Potentiometer.

Now that we have seen how electricity may be set in motion, it becomes necessary to examine the conditions which decide its utility from a practical point of view.

That is to say, we must study the relationships which exist between Current, Potential difference and Resistance, and the application of the units by which these dimensions are measured.

A reference to Fig. 2 will help us easily to understand these relationships. The higher the jar J is raised with respect to the tube G the greater will be the amount of water transferred to the latter. The raising of the jar of course determines the pressure exerted by the water contained in it.

If now the rubber tube T be removed and another one of much smaller diameter be substituted, a less volume of water would pass through it in a given time than would pass through the original tube. If this tube were then filled with sand an even smaller quantity of water would pass in the same time. It is thus seen that the dimensions of the path through which the water flows affect the volume of the water allowed to pass in a given time

If we turn to the electrical circuit shown in Fig. 1 we find an exactly similar state of affairs. The instrument E is capable of giving us an idea of the amount of electricity flowing in the circuit, a large deflection of the needle N indicating the passage of a higher quantity than that indicated by a small deflection.

We find by experiment that if the wires FF are replaced by extremely fine wires of the same material a much smaller deflection of the needle results. The quality

in virtue of which the wire affects the passage of electricity is its resistance, and we find that under certain circumstances the amount of current varies inversely as this resistance.

We understand by this that if the resistance be doubled the current will be halved, or that if the resistance be halved the current will be doubled.

Again, if by some means we can increase the difference of potential between A and B, we find the current is increased in a direct ratio, which is to say, that when the difference of potential is doubled the current becomes doubled, and if the difference of potential is halved the current becomes halved.

Ohm's Law.—From these two relationships a German physicist named Ohm formulated the following law, which is known as "Ohm's Law"—

Current equals Pressure divided by Resistance.

If the letter C be used to represent current, E to represent pressure or electro-motive force, and R to represent resistance, this law can be written thus—

$$C = \frac{E}{R}$$

Now the ampère is the unit of current, the volt is the unit of E.M.F., and the ohm is the unit of resistance. Therefore in any circuit where two of these quantities are known it is easy to calculate the third. It is easily seen that the relationship existing between these units may be expressed as follows:—

In a circuit of one ohm resistance a pressure of one volt will force a current through the circuit of one ampère.

Resistance.—Now the resistance of any conductor depends on its size and on the particular material of which it is made.

Just as the internal diameter of a water-pipe determines its capacity for conducting a flow of water, so the cross-sectional area of a conducting wire determines its resistance to the passage of a current of electricity. That is to say, the thicker the wire the less will be its resistance. A wire of a certain cross-sectional area will have twice the resistance of a wire of twice this area.

Just as greater force is required to send water through a long pipe than is required to send it through a shorter one, so greater pressure is required to send electricity through a long conductor than through a short one. A wire three miles long has three times the resistance of a similar wire only one mile in length.

Again, if two wires are taken of the same length and cross-sectional area but of different materials, they are found to have a different resistance. The resistance of a unit cube of any material is called its specific resistance.

We can sum up the above observations as follows:—

1. Resistance is inversely proportional to cross-sectional area.
2. Resistance is directly proportional to length.
3. Resistance is directly proportional to the specific resistance.

Therefore resistance equals specific resistance multiplied by length divided by cross-sectional area, or where R represents resistance, l represents length, a represents cross-sectional area, and ρ represents specific resistance—

$$R = \rho \times \frac{l}{a}$$

ρ is a Greek letter pronounced "rho."

As wires have a circular cross-sectional area the formula for the calculation of the area of a circle may be given—

$$\text{Area} = \frac{\pi \text{ diameter}^2}{4} = \cdot7854 \times \text{diameter}^2$$

since π (pronounced "pie"), which is the ratio between the circumference and diameter of a circle, equals 3·1416.

The C.G.S. Units.—Most electrical measurements are made in the C.G.S., or centimetre, gramme, second system, in preference to the foot, pound, second units, as the metric system is so much easier than the English system for calculation purposes. Therefore, in speaking of the resistance of an unit cube of a metal as being the

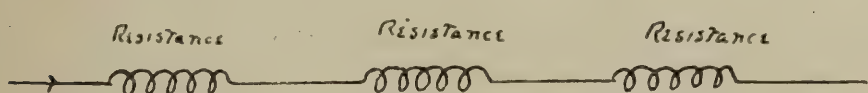


Fig. 16.—Resistances in Series.

specific resistance of that metal, we refer to a cube measuring one centimetre along each of its edges.

Arrangement of Resistances.—If a current passes through several resistances in succession, as in Fig. 16, the resistances are said to be joined in series.

If the current divides at a certain point and passes through resistances in such a manner that the different portions reunite at another part of the circuit, as in Fig. 17, they are said to be joined in parallel.

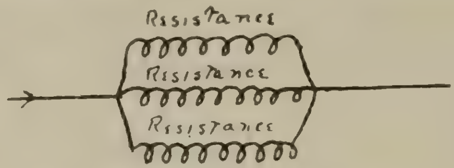


Fig. 17.—Resistances in Parallel.

The adding of resistances in series is equivalent to increasing the length of the conductor so that the total resistance is equal to the sum of the separate resistances.

When resistances are arranged in parallel, however, several paths being offered for the passage of the current, it is equivalent to increasing the cross-sectional area of the original conductor. The current passing through the separate resistances is proportional to the conductivity of each path.

The conductivity of a conductor is the reciprocal of its resistance—that is to say, it is equal to one divided by the resistance in ohms.

We can say, therefore, that the amount of current passing through different resistances joined in parallel is proportional to the reciprocals of the resistances, and that the total resistance of resistances in parallel is equal to the reciprocal of the sum of the reciprocals of the separate resistances.

Now, if we take a circuit in which it is desired to find the current flowing at a given E.M.F., it is necessary to take into account the total resistance of every part of the circuit. If the source of supply be a primary cell, the *internal resistance* of the cell must be reckoned with. This varies in different types of cell, and depends on—

1. The resistance of the elements, depending on the material and size.

2. The resistance of the electrolyte, depending on the material and the distance between the plates.

Arrangement of Cells.—When two or more cells are joined together in order to produce greater effects, the arrangement is called a battery. The cells, like the resistances mentioned, may be arranged in either series or parallel.

To join cells in series the negative pole of one cell must be connected to the positive of the next, and so on, as in

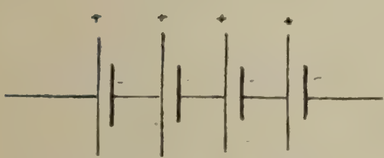


Fig. 18.—Cells in Series.

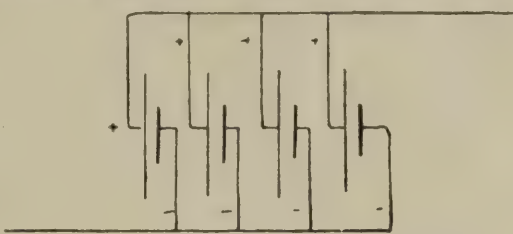


Fig. 19.—Cells in Parallel.

Fig. 18. To join them in parallel all the negative poles must be connected and all the positives, as in Fig. 19.

A combination of these two arrangements may be taken, known either as a parallel-series or a series-parallel arrangement. Such an arrangement is shown in Fig. 20.

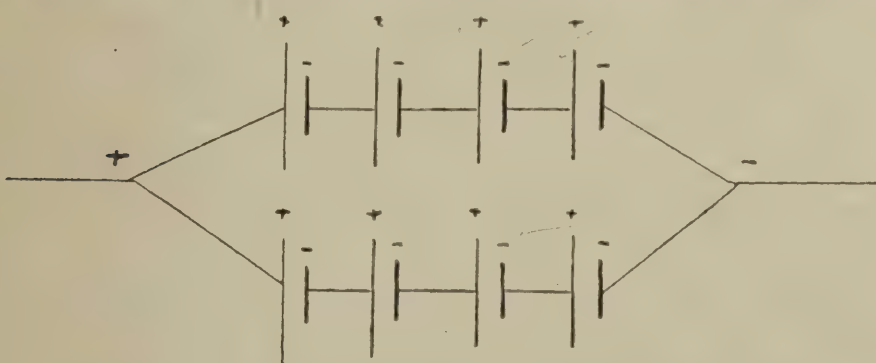


Fig. 20.—Series-Parallel or Multiple Arc Arrangement of Cells.

As is seen in the figures, it is usual to represent the positive pole of a cell by means of a long thin line and the negative by means of a shorter and thicker one.

When a number of cells are joined in series the total pressure or E.M.F. is equal to the sum of the individual E.M.F.'s, and the total internal resistance of the battery is equal to the sum of the individual internal resistances.

In a parallel arrangement of the cells, provided that

they are all of the same type, the total E.M.F. is equal to the E.M.F. of one cell and the total internal resistance is equal to the internal resistance of one cell divided by the number of cells in parallel.

A series arrangement is made when greater pressure is desired, and a parallel arrangement when quantity is the chief object. The latter arrangement is often referred to as being connected in "multiple arc."

We are now in a position to elaborate the previously given simple mathematical expression of Ohm's Law in order to provide full equations for the calculation of the quantities in more complicated circuits.

Thus if R represents the total external resistance in a circuit, r represents the internal resistance of each cell employed, E represents the E.M.F. of each cell, n represents the number of cells used in series, and p represents the number of cells or rows of cells in parallel, it will be easily seen that the following equations hold good for the three different arrangements:—

Series. $$C = \frac{nE}{R + nr}$$

Parallel. $$C = \frac{E}{R + \frac{r}{p}}$$

Series-Parallel. $$C = \frac{nE}{R + \frac{nr}{p}}$$

Maximum Current from Battery.—A little consideration of Ohm's Law shows us that we obtain the maximum amount of current from a given number of cells when the external resistance is equal to the internal resistance of the battery.

Let N equal the number of cells.
n equal the number of cells in series.
p equal the number of groups in parallel.
r equal the internal resistance of each cell.
E equal the E.M.F. of each cell.
R equal the external resistance.
Obviously np equals N.

It is required to prove that to obtain the maximum current we must arrange the cells so that

$$R=\frac{nr}{p} \text{ (total internal resistance.)}$$

As stated above

$$C=\frac{nE}{R+\frac{nr}{p}} \quad \text{.....................(1)}$$

From which we obtain the following—

$$C=\frac{npE}{Rp+nr} \quad \text{.....................(2)}$$

But

$$np=N \quad \text{.........................(3)}$$

By substituting in equation (2)

$$C=\frac{NE}{Rp+nr} \quad \text{.....................(4)}$$

Now NE is a constant. That is to say, its value cannot be changed without altering the total number of cells. Therefore in order that the expression in equation (4) may have a maximum value the denominator $(Rp+nr)$ must be a minimum.

In order to find the condition when this denominator is a minimum we must first square both sides of equation (4), giving us

$$C^2=\frac{N^2E^2}{(Rp+nr)^2} \quad \text{..................(5)}$$

Now

$$(Rp+nr)^2=(Rp-nr)^2+4Rpnr$$

substituting this value in equation (5) we get

$$C^2=\frac{N^2E^2}{(Rp-nr)^2+4Rpnr} \quad \text{............(6)}$$

Now $(Rp-nr)^2$ must always possess a positive value, being a perfect square, and therefore in order that the denominator in equation (6) may be as small as possible $(Rp-nr)^2$ must be equal to zero, which is when

$$Rp-nr=0$$

or

$$R=\frac{nr}{p}$$

When we have a number of cells at our disposal and we desire to find out the arrangement which will give us the maximum amount of current through a circuit of known external resistance, the following formula can be used. Using the same lettering as before:—

$$n=\sqrt{\frac{NR}{r}}$$

or to express the relationship in words, the number of cells in series is equal to the square root of the product of the total number of cells and the external resistance divided by the internal resistance of one cell.

The proof of the correctness of this formula is as follows. As previously proved

$$R \text{ must equal } \frac{nr}{p} \quad \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

But $N=np$ therefore $p=\dfrac{N}{n}$

Substituting in equation (7) we get

$$R=\frac{nr}{\frac{N}{n}}=\frac{n^2r}{N}$$

or

$$n^2=\frac{RN}{r}$$

therefore

$$n=\sqrt{\frac{RN}{r}}$$

Now n equals the number of cells to be used in series, and it only remains to divide the total number of cells by this figure to obtain the number of parallel groups.

In practice it will be found that the figures arrived at by this method of calculation are very seldom whole numbers. As it is impossible to have a fraction of a cell, however, it is necessary to make the arrangement most nearly approaching the result of the calculations. It is necessary, of course, that there should be an equal number of cells in each series group, otherwise we should have one group forcing a current through another on account of the unequal E.M.F.'s which would be set up,

a state of affairs which must very carefully be avoided when using cells in parallel, as it would result in the running down of one lot, and cause serious deterioration.

Potential Slope.—So far we have only considered Ohm's Law with respect to the whole length of any circuit. It holds good, however, for any portion of a circuit, and consequently, provided that we know the resistance between any two points, we can easily calculate the difference of potential between these two points.

Let us take a simple case for example. We will assume that the cell in the accompanying figure (Fig. 21) has an

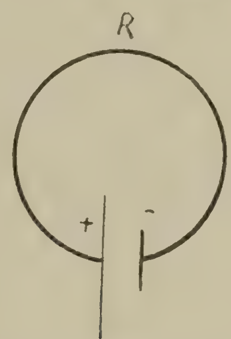


Fig. 21.—Simple Circuit.

E.M.F. on open circuit of two volts and an internal resistance of two ohms. If we connect up to the external circuit R which we will consider to have a resistance of two ohms, from Ohm's Law we have

$$C=\frac{2}{2+2}=\frac{1}{2}$$

that is to say, a current of half an ampère is flowing in the circuit. Now let us take that portion of the circuit consisting of the cell alone and again apply the law. If

$$C=\frac{E}{R},\ E=C\times R \text{ therefore } E=\frac{1}{2}\times 2=1$$

which tells us that on the closed circuit the difference of potential between the two poles of the cell has fallen to one volt, or that a pressure of $2-1$ volts has been taken up to force a current of half an ampère through the internal resistance of the cell. If the difference of potential be calculated through the external portion of

the circuit in a similar way it will also be found to be one volt.

If the resistance of the external portion of the circuit be great in comparison with the internal resistance the latter can be neglected, as its introduction into the denominator will only make a very slight difference in the final result of our calculation.

Let us consider a circuit of the following type (Fig. 22). The external resistance between A and B is 20 ohms.

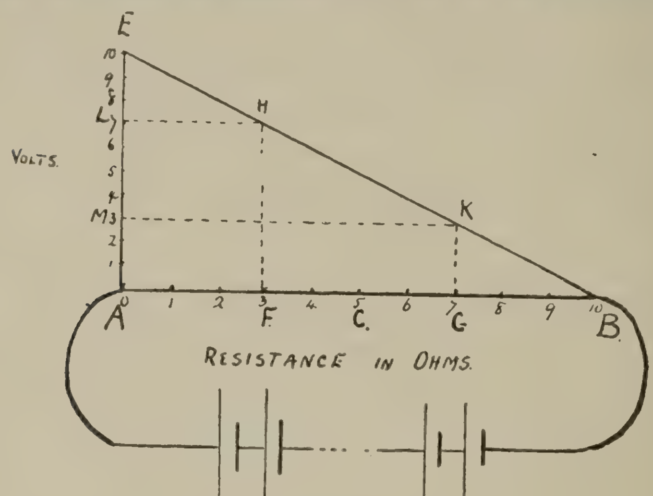


Fig. 22.—Potential Slope.

The E.M.F. of the battery shall be taken to be of such a quantity as to produce a difference of potential between A and B of ten volts. Now if the wire be of uniform size between A and B, according to the laws of resistance half the wire will have half the resistance of the whole, therefore the resistance between A and C (which latter point we will take to be equidistant between A and B) will be 10 ohms. Applying Ohm's Law the difference of potential between A and C is found to be 5 volts.

A very simple method of finding the difference of potential between any two points of the wire AB is as follows. From A draw a vertical line AE and allow its full length to represent 10 volts. Now divide it into ten equal parts Each part will represent 1 volt. From E draw a line to B.

The line EB is known as the potential slope. It affords us a means of quickly finding out the difference

of potential between, say, the two points F and G. Proceed as follows. From F and G draw two perpendiculars FH and GK. From H and K draw the lines HL and KM perpendicularly to the line AE. Then the length of the line LM will give the difference of potential between F and G.

The Potentiometer.—Although the necessity of using the above method for calculating drop of potential may never arise during the work of a wireless operator, it will enable him to better understand the working of an instrument called a potentiometer, which is used in a type of receiver to be described later. This is an instrument used for varying the difference of potential between two certain points at will, and consists of a resistance wire from which tappings can be taken, one usually being fixed and the other variable, by means of a sliding contact as in the accompanying figure (Fig. 23).

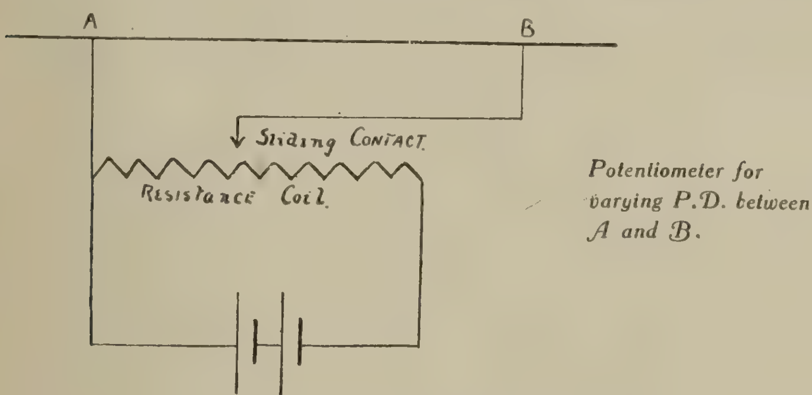


Fig. 23.—Potentiometer.

CHAPTER V.

Magnetism.

Lodestone—Magnetism—Artificial magnets—First law of magnetism—Magnetic induction—Theory of magnetism—Lines of force—Attraction and repulsion—Permeability—Magnetic field—Terrestrial magnetism.

Before we can properly study certain other qualities which must be considered in applying current electricity to wireless telegraphy, it is necessary to know something about magnetism.

Lodestone.—In certain parts of the world—notably Norway, Sweden, and parts of America—a peculiar type of iron ore is found. One of the properties of this mineral is that if a piece of it be suspended so that it is free to turn in a horizontal plane it invariably takes up a position pointing north and south. The ancients utilised this property of the ore as a means of guiding their ships across wide tracts of ocean, and for this reason it became known as leading-stone, or lodestone. Originally the mineral was found mostly in Magnesia, in Asia Minor, and it is from this source that such words as magnet, magnetism, magnetic, etc., have been derived. Lodestone has the power of imparting this property of magnetism to certain other substances.

Artificial Magnets.—If a piece of hard steel be stroked continuously in the same direction with a piece of lodestone, after a while it will be found that the steel possesses similar evidences of magnetisation. If suspended by means of a thread, it will be found to always point in a northerly and southerly direction. It will be found to possess the power of picking up pieces of iron or steel, and if it be plunged into a quantity of iron filings and withdrawn it will be seen that the filings have adhered to it, particularly at two well defined points. These points are known as the poles of the magnet, and are called

the north-seeking and south-seeking poles, or simply the north and south poles respectively.

The First Law of Magnetism.—If two such steel magnets be taken and one of them be suspended, on bringing the second one near it in various ways, the following effects are produced.

On approaching the north pole of the suspended magnet with the north pole of the other, the former swings round in a direction which places its north pole as far away as possible from the approaching north pole of the second magnet.

A similar effect is produced when the south pole of the free magnet is made to approach the south pole of the suspended magnet. When the north pole of the free magnet is brought towards the south pole of the suspended magnet the latter is found to swing so that it comes to rest in a position as near as possible to the approaching north pole.

From these facts we see that—

1. Like poles repel each other.
2. Unlike poles attract each other.

Of course, although the north-seeking pole is usually termed the north pole, it is in reality a south pole, and the south-seeking pole is really a north pole. This will be readily understood when it is remembered that unlike poles attract.

Magnetic Induction.—If a steel magnet be taken and a piece of iron be placed in contact with it or in close proximity to it, this piece of iron is found to possess magnetic properties, and it can be proved that the end of the iron nearest the pole of the magnet possesses opposite polarity to that pole.

It is said that magnetism has been induced in this piece of iron. If the magnetising influence be removed, by either taking away the magnet or the piece of iron, the latter will be found to contain no remaining trace of magnetism, or at least very little.

On performing the same experiment with a piece of hard steel, however, it is found that it retains a certain amount of magnetism even after the magnetising force has been removed. This magnetism is called residual

magnetism, and it is found that the harder the steel used the greater is the amount of this residual magnetism.

Under the heading "Artificial Magnets" it was stated that a piece of hard steel could be magnetised by stroking with a magnet. If the same experiment is tried with a piece of soft iron no or very little permanent magnetisation results.

Theory of Magnetism.—When a steel magnet is subjected to blows from a hammer it is found to lose its magnetism. When a piece of steel which is undergoing the process of magnetisation is tapped with a hammer in a certain way the magnetisation is accelerated.

When a magnet is heated to a red heat it loses its magnetic properties.

When a very long magnet, say a magnetised knitting-needle, is broken up into a great number of small parts, each part is found to be a complete magnet in itself.

All these facts agree with the theory that has been put forward in explanation of magnetism. It is thought that all the molecules in a magnetic substance are complete permanent magnets. Under ordinary circumstances these infinitely small, permanent magnets are lying in a haphazard fashion in all sorts of directions, so that the effect of an equal number of north and south poles is to neutralise the total forces.

Under the influence of some strong magnetising agent, however, the molecules are rearranged so that they are lying in symmetrical lines throughout the length of the

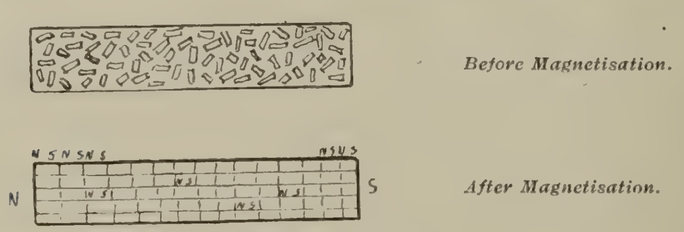


Fig. 24.—Arrangements of Molecules before and after Magnetisation.

magnetic substance in such a manner that the unlike poles of each adjacent molecule are together. The accompanying diagram will help to explain this idea. (Fig. 24.)

It will be seen from this theory that it is impossible to have a magnet with only one pole.

This theory is quite consistent with the behaviour of steel and soft iron under magnetising influences, for it can be readily understood why hard steel, in which the molecules are more closely packed than in soft iron, takes a longer time for the rearrangement to take place. At the same time, once this rearrangement has been accomplished it requires a correspondingly great force to place the molecules in their original state of chaotic disorder, thus explaining why hard steel retains its magnetic properties indefinitely.

Lines of Force.—As a magnet has the power of inducing magnetism in a neighbouring piece of iron, its force must be exerted at a distance, and we can easily find in what manner this force is distributed round a magnet.

Let us take an ordinary bar magnet and lay over it a sheet of stout paper. If then a pepper-box filled with fine iron filings be used to sprinkle the filings over the paper, each separate filing, under the influence of the magnet, becomes a small magnet, and the filings arrange themselves with unlike poles together along certain lines closed upon the ends of the bar magnet, as in Fig. 25. We thus

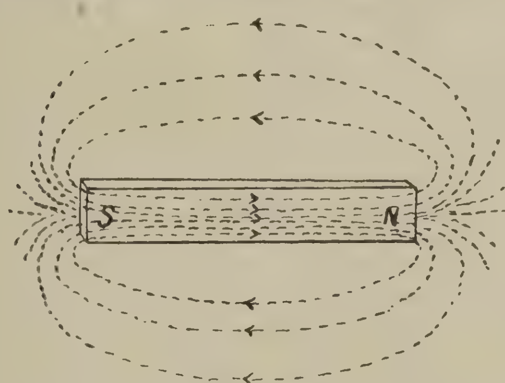


Fig. 25.—Magnetic field round Bar Magnet.

see that the force of a magnet appears to be along these lines defined by the filings, and consequently these lines are called lines of force.

By taking different combinations of magnets we can use the filings to demonstrate the effect of one magnet upon another, and so on. For instance, in Fig. 26, where the like poles of two bar magnets are shown together, the lines of force due to each are seen to run in the same direction in a line at right angles to the length of the

magnets. This explains the force of repulsion which exists between two like poles.

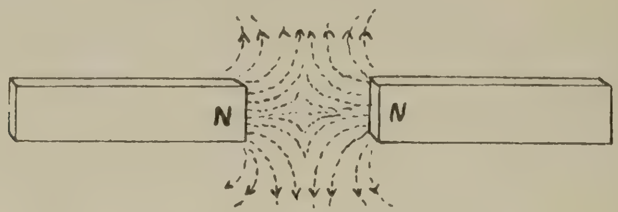


Fig. 26.—Magnetic Field between Like Poles.

In the next diagram, Fig. 27, where the unlike poles of two bar magnets are adjacent to each other, the lines appear to stream from the pole of one into the pole of the other. In this case the lines of force may be likened

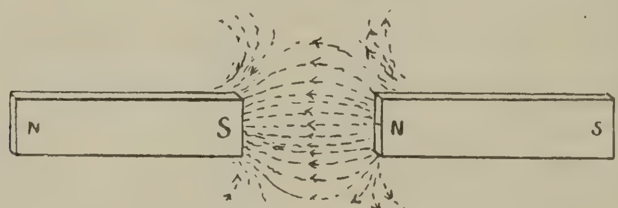


Fig. 27.—Magnetic Field between Unlike Poles.

to stretched elastic threads between the two poles, thus tending to bring them nearer together and explaining the force of attraction between two like poles.

In order to show that the lines of force do not exist only in one plane, but that they pass through the medium surrounding a magnet in all directions, an experiment may be made in which only one pole is used. If the paper be placed over one pole of the magnet in a plane at right angles to its length and the filings be sprinkled over the paper, they are seen to take up a position as in Fig. 28.

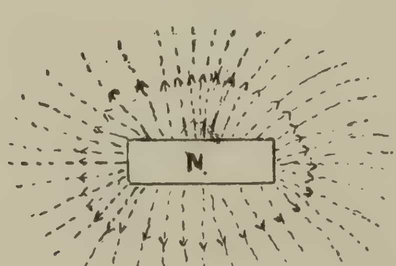


Fig. 28.—Magnetic Field round One Pole of Magnet.

Again, if we take a bar magnet with a piece of iron near one of its poles we find the distribution of the lines of force as shown in Fig. 29. The lines of force appear to be bent over from their original position as though the

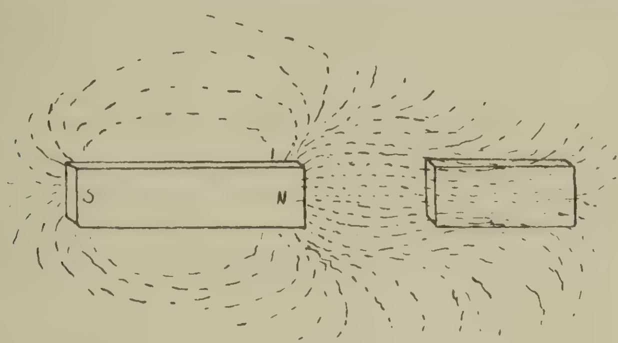


Fig. 29.—Distortion of Field due to Soft Iron.

piece of iron offers an easier path, or, in other words, as though the piece of iron has the power to concentrate the lines of force through a smaller space.

Permeability.—The property possessed by magnetic substances of concentrating the lines of force is known as permeability. It is found that soft iron has much greater permeability than steel, by which we mean that it has a much greater concentrating effect on the lines of force than steel.

It is found that the permeability decreases as the magnetising force increases. This implies, therefore, that after a certain strength of the magnetising force has been reached, any further increase will not result in any large increase of the number of lines passing through the iron. The latter is then said to be in a state of magnetic saturation.

Magnetic Field.—The whole medium which is permeated or occupied by magnetic lines of force is called a magnetic field. Magnetic fields are compared one with another in terms of their intensity. A magnetic field of unit strength is one in which it is presumed that only one line of force exists per unit area. That is to say, that if a plane at right angles to the direction of the lines of force be taken and divided up into squares measuring one centimetre each way, in a field of unit intensity only one line of force would pass through each square. Thus,

if, say, ten lines of force exist per unit area the field is said to be more intense than one in which less than ten lines exist.

Terrestrial Magnetism.—The earth is presumed to be a huge magnet. It has a north and a south pole, between which poles exist lines of force similarly disposed as in the case of a bar magnet.

A compass needle or any suspended magnet always sets itself along these lines of force.

The magnetic poles are situated at some distance from the geographical poles, and from London the north magnetic pole is some $16\frac{1}{4}$ degrees to the west of the true north. This angle is called the angle of declination, and is found to vary from year to year.

If a magnet be suspended in such a manner that it can swing in a vertical plane, even though it be perfectly balanced before being magnetised, it is found to incline towards the north pole. The angle of inclination is called the angle of dip, and at the north magnetic pole the needle is found to point straight downwards.

In diagrams illustrating magnets and the lines of force set up by them, it is usual to fix arrow heads to the lines. This does not indicate a flow of current along these lines, but merely shows the direction of the force exerted.

The force is always exerted in a direction from the north pole to the south pole outside the magnet, and from the south pole to the north pole inside the magnet, and is therefore the direction in which a little north pole would move if placed on the line of force outside the magnet.

CHAPTER VI.

ELECTRO-MAGNETS.

Deflection of magnet by current—Ampère's rule—Multiplier or galvanometer—Electro-magnetic field—Maxwell's corkscrew rule — Solenoid — Electro-magnets — Ampère-turns — Electro-magnetic induction—Induction coil.

WE must now bring our attention back to a statement made in the first chapter, where it was mentioned that the wire connecting the two poles of a simple cell possesses peculiar properties. A magnetic needle in the vicinity of such a wire carrying a current is affected in a definite manner.

If the magnetic needle be placed directly over a wire in such a manner that its axis is parallel to the wire and a current be forced through the latter, the needle is found to deflect.

The direction of this deflection depends on the direction of the current through the wire and on the position of the poles of the needle.

Ampère's Rule.—The famous scientist who gave his name to the unit of current formulated a rule by which the relation between the deflection and the direction of the current can be very easily remembered.

If a man were to swim along a wire in the direction of the current-flow, with his hands outstretched and with his face pointing towards the needle, the north pole of the needle will always turn to his left hand.

If now a wire be taken of such a shape that after the current through it has passed in one direction over a magnetic needle it can pass in the directly opposite direction under the needle, whatever the power producing this deflection may be, it should now have a greater effect. For, applying Ampère's rule, the swimmer would now be on his back and his left hand would be in the same

direction as that already taken by the north pole of the needle.

"*Galvanometer.*"—If then we take a coil of wire, wound as in the accompanying diagram (Fig. 30), a small

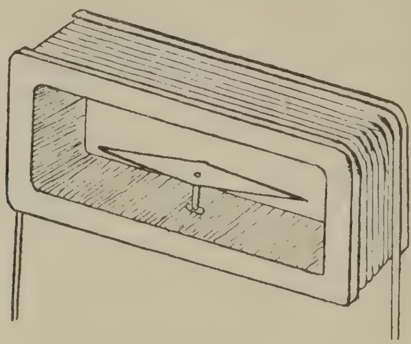


Fig. 30.—"Multiplier" or "Galvanometer."

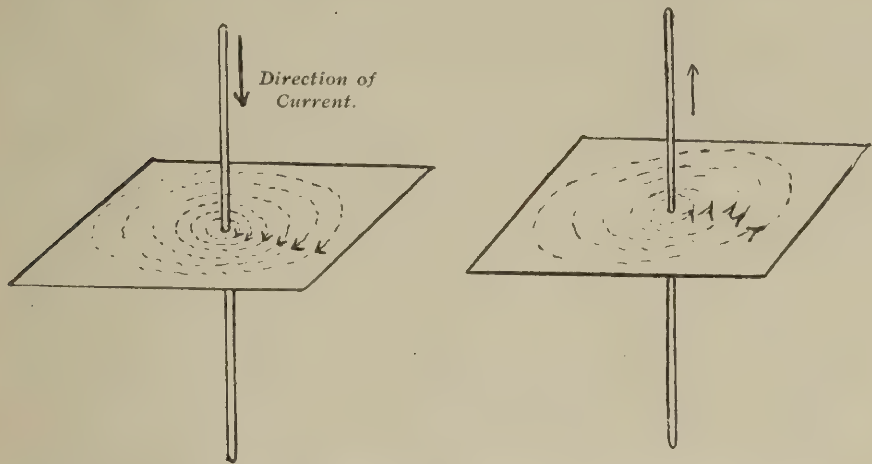
current produces a sufficiently accumulated effect, after passing through the many turns, to cause a considerable deflection of the needle.

This arrangement is often called a "multiplier," and is used largely to detect the presence of a current. When used for this purpose it is made up into a convenient form and called a "galvanometer." More will be said on this subject later. Just as a magnet has been shown to have the power of inducing magnetism in a piece of iron at a distance from it, so a current passing through a wire has this power.

A very simple experiment sufficiently demonstrates the fact that magnetic lines of force are set up by the passage of a current. In Fig. 31, AB is a wire placed vertically through a sheet of stiff paper. If a current be now forced through the wire, and iron filings be scattered over the paper, they are found to take up a position in the form of concentric circles with the wire as a centre. It is found that if the current be increased the influence over the iron filings is more strongly marked, and that if it be decreased the opposite effect is produced.

Each of the iron filings whilst under the influence of the current possesses the properties of a small magnet, and if the polarity of these magnets be examined it is found to depend upon the direction of the current. The current direction and corresponding polarity or direction

of strain along the lines of force is shown in Figs. 31 and 32.



Figs. 31 & 32.—Electro-Magnetic Field round Current-carrying Wire.

A rule, known as *Maxwell's Corkscrew Rule,* provides an easy method of remembering the relative directions of current and lines of force. If we screw a corkscrew in the direction of the flow of current the corkscrew rotates in the direction of the magnetic lines.

The Solenoid.—If a piece of wire be wound in the form of a helix, as in Fig. 33, and a current be passed through

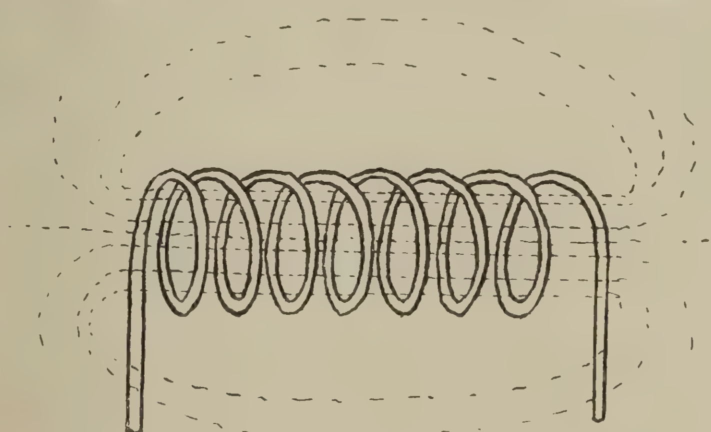


Fig. 33.—Solenoid and "Field."

it, it is found to act in the same manner as a bar magnet. Such an arrangement is called a solenoid, and it is seen by applying the law just given that the lines of force produced around each adjacent turn of wire will give resultant lines of force passing through the centre or

axis of the coil. If this arrangement be suspended so that it can swing in a horizontal plane, it will take up a position pointing north and south. The polarity of course is decided by the direction in which the current is passing through the wire.

Electro-Magnets.—Now let us take a single turn of wire round a thin disc of iron and cut the whole arrangement in two along a diameter of the disc. We should then have a sectional view as shown in Fig. 34.

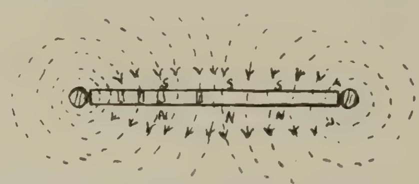


Fig. 34.—Theory of Electro-Magnet.

Imagine that it is possible for us to pass a current through this half-turn of wire and let us examine the effect. The lines of force set up in the form of concentric circles round the wire cut through the iron disc, and in doing so convert each part into a small magnet, so that the disc becomes a bundle of very small magnets all lying with their north or south poles uppermost, according to the direction of the current. If now we take a great number of similar arrangements we should have the equivalent of a bar of iron wrapped round with a coil of wire (Fig. 35), and we should have the small magnets

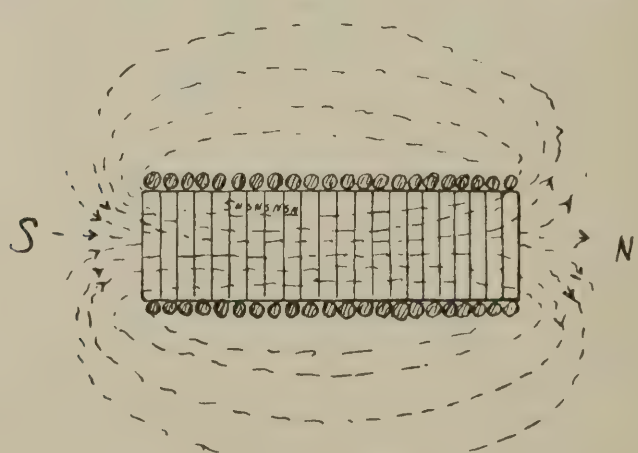


Fig. 35.—Electro-Magnet.

lying in a similar position to that taken up by the molecules of the bar magnet, as explained under the heading, "Theory of Magnetisation."

A bar or rod of iron round which is wound a coil of wire conveying a current is called an electro-magnet.

Now, in a previous chapter it has been explained that the permeability of iron enables it to concentrate lines of force. It will be easily seen, therefore, that we have here a means of producing a very powerful magnet.

As was explained a little way back, the intensity or strength of a magnetic field depends upon the strength of the current producing it. In the case under consideration, therefore, any increase in the current will produce a corresponding increase in the magnetism of the iron bar. Again, if we increase the number of turns of wire round the bar we have a greater number of lines of force passing through it.

We can say, then, that the strength of an electromagnet depends on the number of ampères flowing and upon the number of times these ampères pass round it, or, as it is more usually expressed, the strength depends on the ampère-turns.

If a piece of steel be used instead of a piece of iron, after the current has been cut off it is found to retain some of the magnetism. A piece of soft iron, however, loses almost all its magnetism, and use is made of this fact in the designing of many pieces of wireless apparatus. At the same time the magnetic effect produced in a piece of soft iron is greatly in excess of that produced in a piece of steel with the same ampère-turns on account of the higher permeability of soft iron. In the designing of an electro-magnet account must be taken of the saturation point, for after a certain increase in the number of turns used with a certain current has been reached, any further increase would be waste.

Electro-Magnetic Induction.—It has already been shown that a magnetic field is set up round a conductor through which a current is passing. Faraday discovered that the inverse of this action can take place, and that when magnetic lines of force cut a conductor or vary in such a manner that the number of lines cutting the

conductor is changed, an E.M.F. is induced in that conductor.

Let AB represent a conductor to the ends of which a sensitive galvanometer, G, is connected (Fig. 36). If the

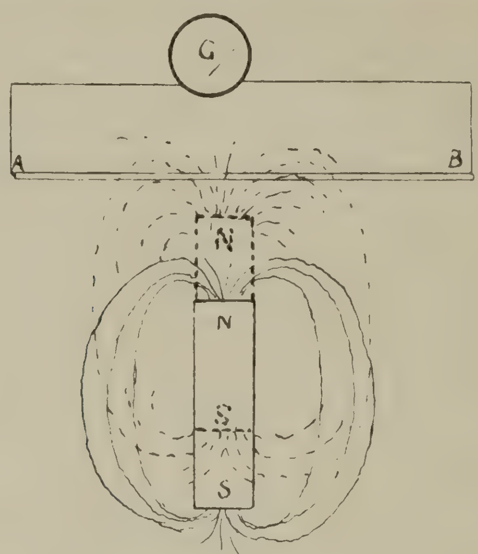


Fig. 36.—Induction.

bar magnet, NS, be brought quickly towards the conductor a deflection of the needle of the galvanometer takes place which denotes that a current has been set up in AB. The needle is found to return immediately to its original position, thus showing that the current set up is only of a momentary nature.

If the magnet be rapidly withdrawn a second deflection of the needle takes place, this time in the opposite direction, and this also is only of a momentary nature.

During the motion of the magnet the lines of force set up by it cut through the conductor in varying number. The nearer the magnet is brought the greater is the number of lines of force cutting through AB, and in accordance with the above law a current is set up. When the magnet has come to rest, the lines of force being stationary, no further induced effect is produced, and the momentary nature of the current is explained. When the magnet is removed the number of lines cutting through AB is rapidly lessened and a current is once more induced, but in the opposite direction to the first.

Now if the time occupied in moving the magnet towards the conductor be varied we find the following effect. The quicker the movement the greater is the induced E.M.F. Thus, if the movement were to take place in one second, we should find an E.M.F. ten times the strength of that which would be produced if the movement occupied ten seconds.

This is expressed in the following important law:—The value of the induced E.M.F. is directly proportional to the rate of change of the number of magnetic lines cutting the conductor.

Now it is readily seen that the same effect is produced when the magnet is kept stationary and the conductor moved, and it is on this principle that the machine called the dynamo is constructed.

The Induction Coil.—It has been stated that if a conductor be approached by a magnet an E.M.F. is set up in it by induction. If the conductor be given the form of a coil of a great number of turns the effect is greatly increased. The effect depends on the rate at which the number of lines of force linked with the conductor varies, and if each line of force passes through a great number of turns it is linked with the circuit a corresponding number of times. Thus in Fig. 37 the thick line repre-

Fig. 37.—Linkage of Line of Force.

sents the conductor and the thin one a line of force linked with it. If the conductor be given three turns instead of two, one of the ends must be bent round and threaded through the closed line of force again. Thus we see that where two linkages existed before three linkages now exist. If then a coil of wire of a great number of turns be brought suddenly into a magnetic field the rate of

change of the number of linkages is enormous and the induced E.M.F. great. It has been pointed out that an electro-magnet may be made to create an intense field, the intensity depending on the ampère-turns. If then an electro-magnet be used instead of an ordinary permanent magnet the effect will be still further heightened. In the case of an electro-magnet, however, it is not necessary to move either the magnet or the conductor, because the field may be set up or dissipated by starting or stopping the current through the electro-magnet coils. Fig. 38 shows such an arrangement. P is the winding

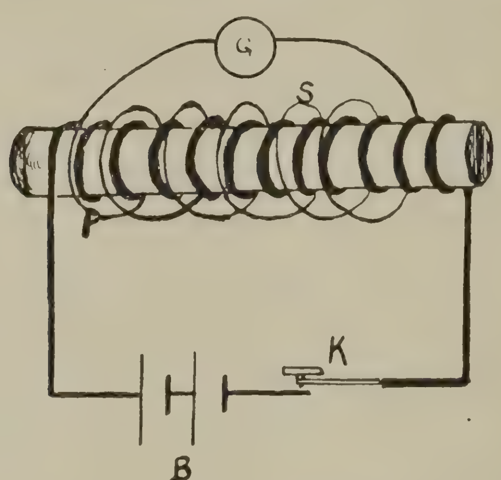


Fig. 38.—Principle of Induction Coil.

of an electro-magnet supplied with current from a battery, B, S is a solenoid consisting of a great number of turns of insulated wire. When the circuit is closed by means of the key, K, the lines of force set up by the magnet pass through the coil, S, and induce in it a momentary current. The momentary nature of this current is indicated by a kick of the galvanometer needle, G, and is due to the fact that the current very soon reaches a constant strength and the number of linkages of lines of force ceases to vary. If the circuit be interrupted, a second induced E.M.F. is created in the opposite direction. It is found that the ratio between the induced E.M.F. and the E.M.F. of the first current is approximately the same as that between the number of turns in the conductor and the number of turns round

the electro-magnet. An arrangement of this sort, used in connection with some means of very rapidly making and breaking the circuit containing the electro-magnet winding and battery, is called an induction coil. A more detailed account of an actual coil will be given later.

The electro-magnet winding is called the primary, and the conductor winding the secondary.

CHAPTER VII.

Dynamo, Motor, Rotary Converter.

Fleming's rule—Current in conductor moving through magnetic field—Alternating current—Sine curve, construction of—Abscissa—Ordinate—Commutator—Brushes—Pulsating current—Armature—Core—Field magnets—Dynamo—Motor—Back E.M.F.—Use of machines either as motor or dynamo—Speed of motor—Field regulator—Starter—No load release—Overload release—Rotary converter—Slip rings—Periodicity—Transformer.

Dynamo.—If we take a coil of wire so arranged that it is capable of being rotated in a magnetic field, according to Faraday's law given in the preceding chapter, we should expect an E.M.F. to be set up in it during rotation, as it would be continuously cutting through the lines of force.

The direction of this induced E.M.F. would vary according to the polarity of the magnets producing the field and according to the direction of rotation. In Fig. 39, N and S are the poles of two magnets. ABCD is a

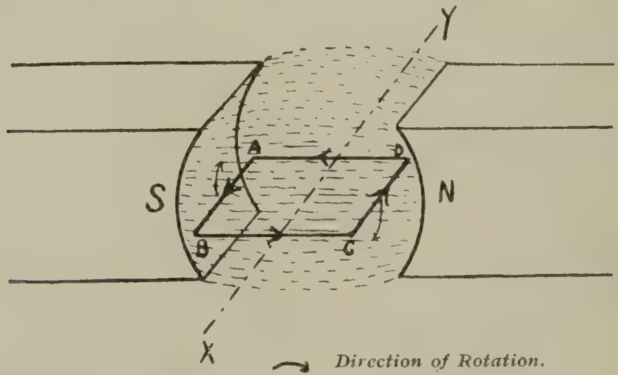


Fig. 39.—Rotation of Conductor in Magnetic Field.

coil of wire capable of rotation on a horizontal axis XY, which is at right angles to the direction of the lines of force, shown as dotted lines between N and S.

Fleming's Rule.—Before discussing the effect produced by rotation it is necessary that Fleming's rule showing the relationship between motion, magnetism and induced current should be given.

Place the thumb, the first and middle fingers of the right hand as nearly as possible at right angles to each other as in Fig. 40, then, if the thumb points in the

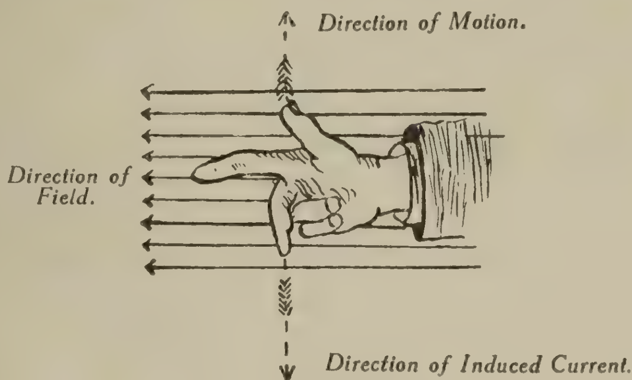


Fig. 40.—Fleming's Rule.

direction of motion and the first finger in the direction of the magnetic lines, the middle finger will point in the direction of the induced current. If the left hand be used the law is applicable for determining the direction of rotation of a motor. This may be remembered by thinking of "thu*M*b" as representing *M*otion and "*F*ore-finger" as representing *F*ield. Applying this simple rule to Fig. 39, we readily see that the direction of the induced current in ABCD, when moving in the direction shown, is as indicated by the arrow heads, for the lines of force in the field are from the north pole to the south pole, as explained on page 44.

As the portion AB is moving upwards against the lines near the south pole, the portion CD is moving downwards through the lines near the north pole, thus the E.M.F.'s produced tend to force a current through the conductor in one direction.

The current only lasts in this direction until the part AB is vertically above CD.

After this position has been passed an application of the rule given shows that the current now induced in AB is in the reverse direction, and that it continues in this direction until CD is vertically above AB.

A little reflection shows that the strength of this current as well as its direction varies.

When the portions marked AB and CD are moving through the upper and lower parts of the circle of rotation, it is seen that for a short time they are practically moving in a direction parallel to that of the lines of force, and consequently as the rate of cutting is so very slow, the induced E.M.F. is correspondingly small. As a matter of fact, when the two parts are vertically one above the other there is no induced E.M.F., or, as it is usually stated, the E.M.F. has a zero value.

The rate of cutting gradually increases until the two parts AB and CD are exactly opposite the centres of the magnetic poles. It is obvious that this is the case, as the conductor at this stage of its rotation is cutting the lines at right angles. At this point, therefore, we find a maximum induced E.M.F. The value of the E.M.F. then gradually decreases until the two parts are once more vertically one above the other, this time the part that was formerly uppermost occupying the lower position.

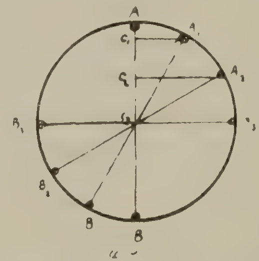


Fig. 41.—Diagram Illustrating Variation of Rate at which Lines of Force are cut.

In Fig. 41 the small shaded circles represent sections of the parts AB and CD of the moving conductor shown in Fig. 39. If the conductor be moved at a uniform speed it will pass into the positions shown at A_1B_1, A_2B_2, and A_3B_3 in equal periods of time, as the angle between any two adjacent positions is 30°.

In passing from AB to A_1B_1 the number of lines of force cut is proportional to the length of the line AC_1. During the next two periods of 30° the cutting of lines is proportional to the lengths of the lines C_1C_2 and C_2C_3, and it will be seen that these lengths gradually increase through the first quarter revolution.

Thus, to summarise the action, we find that during one-half of a revolution a current is induced in the conductor which starts from a zero value, gradually rises to a maximum value, and again gradually falls back to a zero value.

During the next half-revolution a similar rise and fall of E.M.F. takes place, which is, however—as previously pointed out—in the opposite direction.

Now such a current as the one described as being induced in a conductor rotating in a magnetic field is known as an alternating current, and such a current can be graphically represented by what is known as a sine curve.

Sine Curve.—Curve drawing, or curve plotting, as it is usually called, provides a method of showing graphically the relationship existing between different dimensions. Thus if we can represent a certain relationship by such an equation as

$$X = Y + 2$$

we see that the value of X depends on the value of Y, or that if Y increases in value X also naturally increases and vice versa.

The relationship between X and Y for varying values of each can be shown by means of a line as follows. Take a sheet of paper on which a number of straight lines are ruled dividing it up into a number of equal squares. Now the side of one of these squares in a horizontal direction can represent a unit or fraction of a

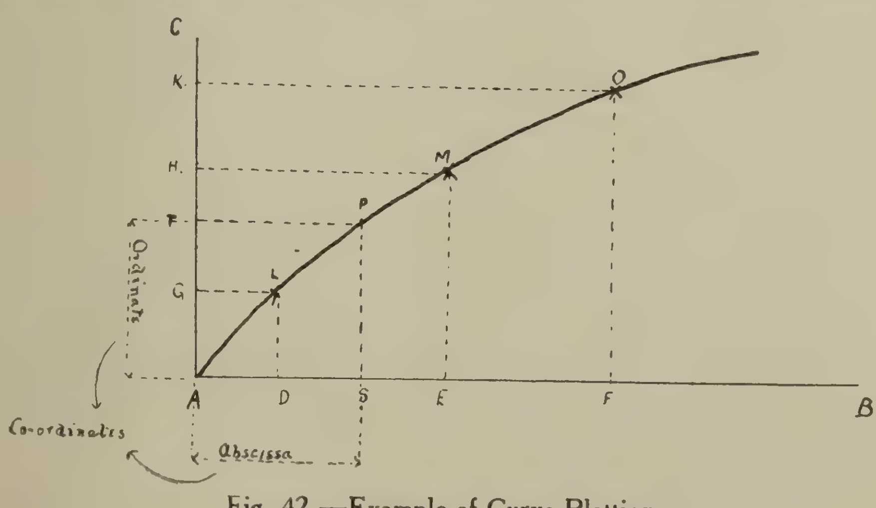


Fig. 42.—Example of Curve Plotting.

unit of the type required to measure X, and the side of one of the squares in a vertical direction can represent a unit or fraction of a unit of the type required to measure Y. Let us then draw a horizontal line AB (Fig. 42) sufficiently long to represent the maximum value of, say, X. Then AA (which is zero) would represent a zero value of X and AB the maximum. From A draw a line AC sufficiently long to represent a maximum value of Y. Then AA would again represent a zero value of Y in this case, and AC the maximum.

Now let us take the points D, E and F along AB representing different values of X. Substituting these values in our equation $X = Y + 2$ we can calculate the corresponding values of Y. Make the points G, H and K represent these values along the line AC. Now if we draw lines from D, E and F at right angles to AB, and also draw lines from G, H and K at right angles to AC, these lines will intersect at the points L, M and O. Through A, L, M and O draw a line. This line is the curve representing the relationship between X and Y. Although the line may be a straight one it is still called a curve, and such a straight line would indicate that X varied uniformly as Y. In the curve described only positive values have been taken for X and Y. If, however, it is desirable to represent negative or minus values for these two quantities the lines AB and AC require to be continued in opposite directions, namely, from A horizontally to the left and vertically downwards.

If any point P be taken on the curve, projections from this point on AB and AC would give the respective values of X and Y represented by such a point. Suppose such projections be the points S and T, then AS and AT are called the co-ordinates of the point P. AS is called the "abscissa," and AT is called the "ordinate." Now let us consider the appearance of a curve showing the relationship existing between the induced E.M.F. and time, which is the factor determining the position of the conductor with respect to the poles of the magnets. Taking a piece of squared paper as above, the squares along AB represent equal periods of time. The squares along AC represent equal values of E.M.F.

Now, commencing with the conductor at rest in such a

position that AB is vertically above CD (Fig. 39), the state of affairs can be represented by the point A as the time is zero and the induced E.M.F. is zero. During the lapse of the amount of time represented by one of the squares along AB a certain number of lines of force have been cut by the moving conductor and an E.M.F. has been set up. The value of this E.M.F. is then measured along AC and the point P found as described above. As time passes the E.M.F. increases up to a maximum point P^1, after which it again falls until CD is vertically above AB (Fig. 39). It will be seen that the curve will take the appearance shown in the first half of Fig. 43. Because the current now commences to pass in an opposite direction, the measurements for the finding of the various points on our curve are now taken below the line. By the time the part AB once more reaches its original position vertically over CD the curve has once more returned to the horizontal line AB.

We thus see that the E.M.F. follows a curve as in Fig. 43 during one complete revolution of the conductor. Such a curve represents what is known as one complete cycle of alternating current.

This form of curve is called a sine curve, and such a curve can be constructed as follows:—

With the point A on a line AB as centre describe a circle of radius AC (Fig. 43). Divide the circumference

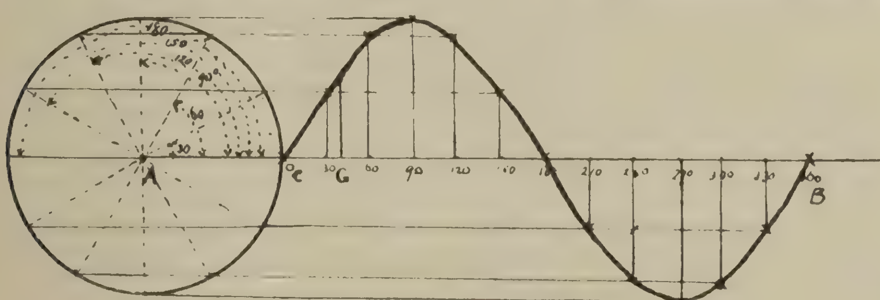


Fig. 43.—Sine Curve.

of the circle and the line CB into the same number of equal parts, say twelve. From the points on the circumference of the circle draw horizontal lines and from the points on the line CB draw vertical lines. Numbering the lines as shown a curve may be drawn through the points of intersection of the correspondingly numbered lines.

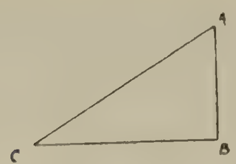


Fig. 44.—Explanation of the Term "Sine."

Now if we take a right angled triangle ABC, as shown in Fig. 44, the ratio of AB to AC is called the sine of the angle ACB. That is to say

$$\frac{AB}{AC} = \text{sine ACB}$$

Turning back then to Fig. 43 we see that if CB represents 360 degrees, and if the maximum ordinate or radius of the circle be called unity, any ordinate FG is proportional to the sine of the angle represented by its abscissa CG. An alternating current which is represented by such a sine curve is called a simple harmonic or periodic current.

Commutation.—Let us now take our attention back to Fig. 39. If the conductor ABCD be cut between C and B and the two ends joined to two half rings of copper mounted on a cylinder of insulating material, as in Fig. 45, we find that the current forced through an external

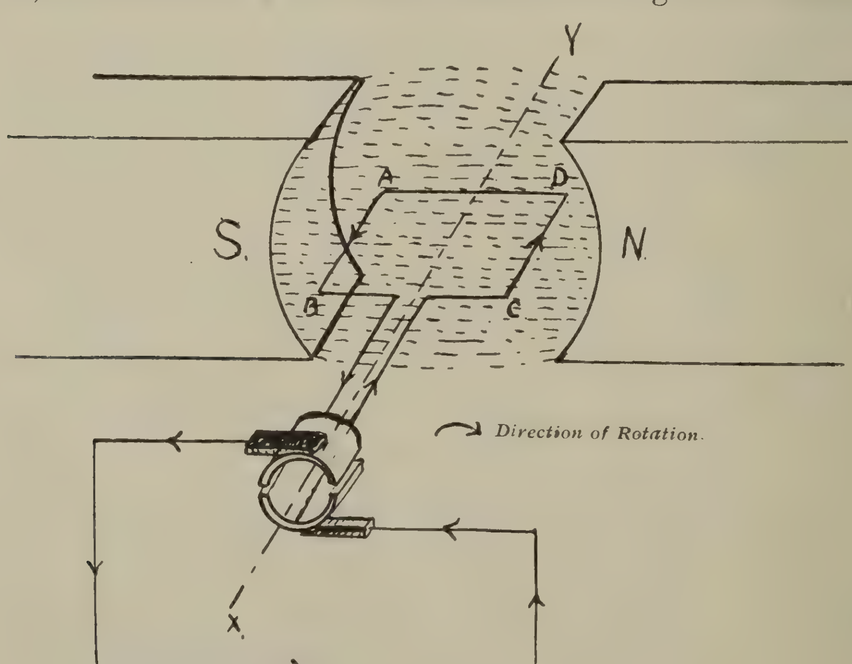


Fig. 45.—Use of "Commutator."

circuit connected to two carbon or copper brushes, so fixed that each one is in contact with the copper ring at diametrically opposite points, is no longer of an alternating type.

In the accompanying diagram it will be seen that although the current in the conductor is still alternating as before, the ends of the external circuit alternately make connection with each end of the conductor, so that the current through the external circuit is continuously passing in the direction shown by the arrow head.

Because this arrangement of two copper half rings on an insulating cylinder commutes or changes the alternating current induced in the conductor into a continuous or direct current in an external circuit, it is called a *commutator*.

Although this external current is called a direct or continuous current it still fluctuates in value, rising from zero to a maximum and so on as before. The curve of this current, however, differs from that of the alternating current in that each half is above the horizontal line, as in Fig. 46.

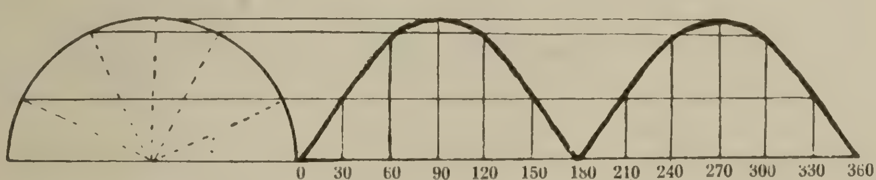


Fig. 46.—Curve of Pulsating Current.

Now let us consider what affects the induced E.M.F.

Let N equal the total number of lines of force between the magnet poles and n equal the number of revolutions per second of the conductor. Then—

The time taken for one revolution equals

$$\frac{1}{n} \text{ second.}$$

The time for one half revolution equals

$$\frac{1}{2n} \text{ second.}$$

The mean rate at which the part AB of the conductor cuts the lines of force is therefore the number of lines

cut divided by the time taken in seconds per half revolution, or—

$$\text{mean rate} = \frac{N}{\frac{1}{2n}} = 2nN \text{ lines per second.}$$

In the ordinary way of reckoning, when a conductor cuts lines of force at the rate of one hundred million per second, an E.M.F. of 1 volt is induced.

100,000,000 is usually written 10^8.

Therefore an E.M.F. of $\frac{2nN}{10^8}$ is set up in the part AB of the conductor under consideration. An equal E.M.F. is set up in the part CD; thus, adding the two together, we see that during one half revolution the mean induced E.M.F. is $\frac{4nN}{10^8}$.

It can now be seen that any increase in the value of either n or N will give a greater value of induced E.M.F. Now it has been previously shown how iron has the power of concentrating a magnetic field. If, therefore, the conductor ABCD be wound round a piece of iron of such a size that it almost takes up all the space between the poles of the magnets N and S, the field through which the conductor has to pass is greatly intensified.

Development of Armature.—In actual practice the iron round which the conductor is wound is of a cylindrical shape, with slots all round the periphery. If a solid piece of iron of this type is rapidly rotated through a magnetic field it acts as a circuit of one turn and *Eddy currents* are set up in it which tend to produce heat and waste energy. In order to prevent these eddy currents the iron "core," as it is called, is built up of thin sheets or laminations of iron all clamped together in the required form.

Now the rotation of one coil of wire even on such an iron core would not produce a very large current, and the current which it would produce would be of too pulsating a nature (as seen by the curve).

If we use several coils of wire, however, suitably disposed round the core and connected to a corresponding number of commutator pieces, we can increase the induced E.M.F., and at the same time so tone down the

pulsating nature of the current as to make it to all intents and purposes a current of constant E.M.F. The connections for a four-coil and four-part commutator arrangement are shown in Fig. 47. Starting from the point a,

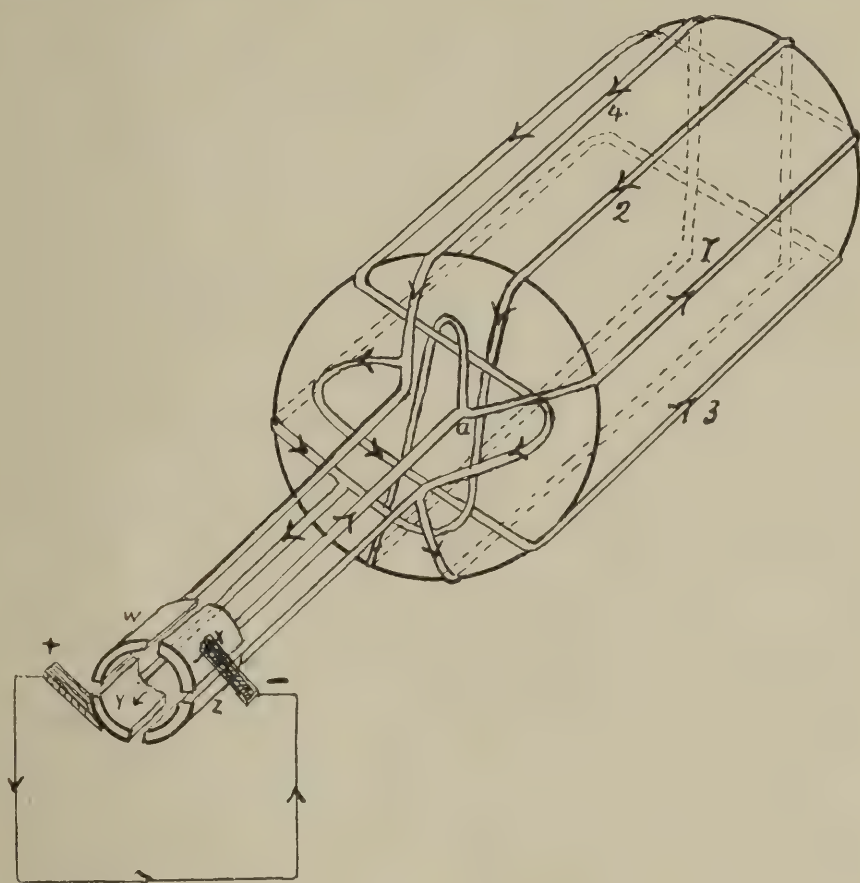


Fig. 47.—4-Coil Armature Winding Connections.

and following the winding round without reference at first to the commutator, it is seen that the coils form a closed circuit and are electrically in series with one another in the order of the numbers marked on them. As regards the connections to the four segments, w, x, y, and z, of the commutator, it is seen that at two of these, x and y, the pressures in the windings are both directed from (at x) or both directed towards (at y) the junction with the connecting wire. At the other two, z and w, one pressure is towards the junction and the other directed from it. If, therefore, brushes be placed on x and y, they supply current to an external circuit, whilst for the

moment z and w are idle bars. The development of the curve for the current produced in the external circuit can be seen in Fig. 48. The two thin curves show the currents

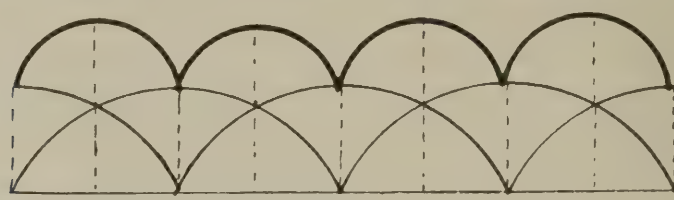


Fig. 48.—Development of D.C. Current.

produced when the brushes are in contact with the two different pairs of commutator bars. The thick curve shows the resultant current, and it is seen that this current never reaches the zero value.

A machine capable of producing current on the principles explained above is called a *dynamo*. The moving portion, consisting of iron core, conductor windings and commutator, is called the *armature*, and the fixed portion consists of the framework of the machine and the magnets, which are called *field magnets*. The latter are never permanent magnets, as shown in the explanatory diagrams, but are invariably electro-magnets.

Armatures are wound in many different ways and are of different types. There are ring armatures, drum armatures (which are of the type described above), and open-coil armatures. The different ways of winding, such as lap winding, wave winding, etc., do not directly concern the wireless operator; and, in fact, it is very seldom that the care of a dynamo ever comes under his charge. There are, however, many text books which give full and mathematical consideration to the subject, and consequently nothing further than the very elementary treatise already given will be dealt with here.

The Motor.—Now, in a dynamo of large size capable of producing a large supply of electricity it is found that considerable power is required to turn the armature. This power is necessary to overcome the force that exists between the lines produced by the field magnets and those produced by the induced current in the armature.

If, then, instead of turning the armature by means of

mechanical power we pass a current through it, lines of force are produced due to the field current and due to the armature current, which lines of force have such an action, one set on the other, that the armature is caused to rotate.

Now, if we presume that the armature of the dynamo is driven in a clockwise direction, the force which the driving power has to overcome must be exerted in a counter-clockwise direction.

We thus see that if a current be sent through the field-magnet windings in the same original direction, and if a current be sent through the armature windings in the same direction as that taken by the induced current when using the machine as a dynamo, the armature will be forced to rotate in a counter-clockwise direction.

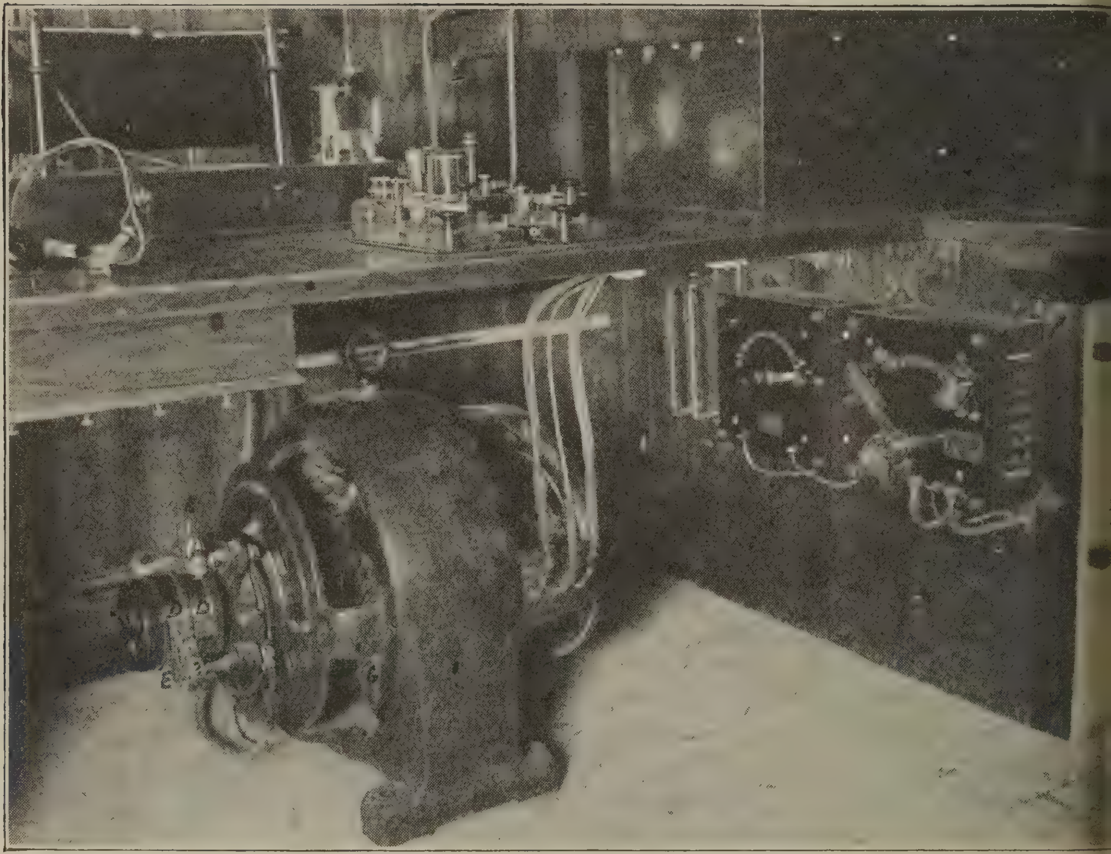
In the case of the machine being used to convert mechanical power into electrical power it has been called a dynamo. When electrical power is converted into mechanical power by such a machine the machine is called *a motor.*

When such a machine is being used as a motor it is readily seen that it can be acting as a dynamo at the same time. That is to say, because the armature is rotating through a magnetic field an E.M.F. will be induced in the armature windings. But it has been stated that the armature is rotating in an opposite direction to the mechanical rotation produced when working as a dynamo, therefore the E.M.F. produced will be in the opposite direction to that produced when working as a dynamo.

Again, it has been stated that the E.M.F. used for driving the machine as a motor is in the same direction as that produced in the armature when the machine is used as a dynamo.

From these considerations we see that the E.M.F. produced by induction when the machine is acting as a motor is in the opposite direction to the E.M.F. of the current used to drive it as such.

The field windings and armature windings of motors and dynamos may be connected up in different ways. The field may be in series with the armature, it may be in shunt with the armature; or a combination of these two arrangements may be used. In a motor used for wire-



ENLARGED VIEW OF ROTARY CONVERTER, ETC., SHOWING DETAIL OF STARTER, ETC., AS INSTALLED IN LONDON SCHOOL.

STARTER : A, Portion of starter handle containing antagonistic spring.—B, No-volt release.—C, Over-load release.

CONVERTER : D, Slip rings.—E, Brush holders.—F, Lubricating oil cup.—G, Field coils.—H, Armature.—K, Guard lamps.

less purposes the great desideratum is a constant speed under varying loads. The type most suitable for these conditions is the shunt-wound variety, and for this reason only this type will be described.

In the accompanying Fig. 49 it is seen how the field winding is in shunt with the armature winding. There is usually a certain amount of residual magnetism in the

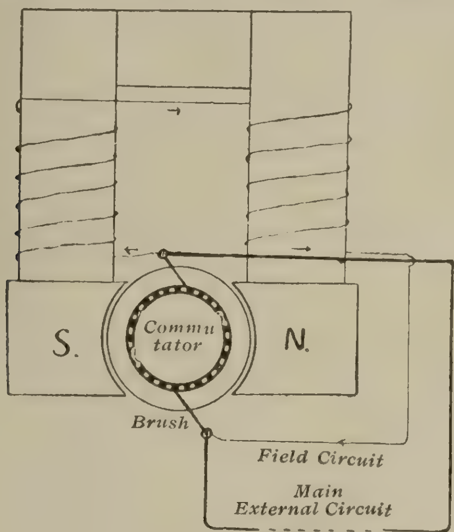


Fig. 49.—Shunt-wound Machine.

field magnets. When using the machine as a dynamo and the armature is revolving, an E.M.F. is induced in it, this E.M.F. producing a current in the field coils, thus increasing the intensity of the field. This increase in field intensity causes a corresponding increase of induced armature E.M.F., which in turn once more still further increases the field current and the magnetic field. This process is continued up to a certain point, when, as previously explained, the cores of the field magnets become saturated and any further increase of field current is only wasted. At this point, unless the speed of the armature is increased, a maximum current is being delivered to the external circuit when it is closed. The value of the current passing through any part of the external circuit depends, of course, on the resistance of the particular part, in accordance with Ohm's law.

Because the current used in the field coils is wasted as far as the external circuit is concerned, care is taken in the designing of the machine to obtain the maximum

effect with the smallest current. In the chapter on electro-magnets it was shown that the amount of magnetism in an electro-magnet depends on the ampère-turns. The field magnets of a shunt-wound dynamo, therefore, are wound with a great number of turns of comparatively thin wire, and thus, the resistance being great, only a small portion of the induced current is taken from the armature to excite them, leaving a greater part for delivery in the external circuit.

The fact that the current passing through the coils of a motor is opposed by a back E.M.F. may be tested experimentally.

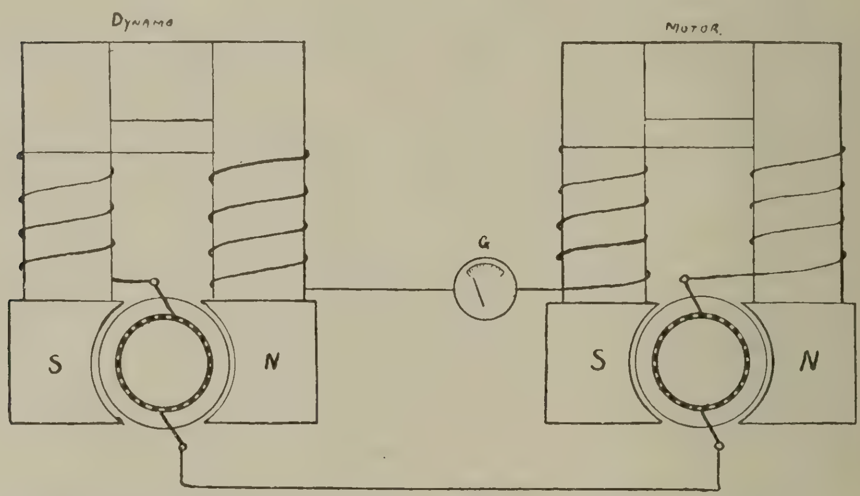


Fig. 50.—Similar Machines used as Dynamo and Motor respectively.

In the accompanying Fig. 50 two machines of identical construction are shown, series-wound machines being taken to simplify the diagram. The one on the left is being driven as a dynamo by means of, say, a steam engine. This dynamo generates current, which is forced through the windings of the machine on the right. It will be seen that the direction of the current through the field windings in either machine is the same, but that the current through the dynamo armature is in the reverse direction to that through the motor armature. The latter will therefore rotate in the same direction as the dynamo is being driven. G represents a galvanometer in the circuit. The current through the motor causes the armature to

rotate, and a back E.M.F. is produced, as shown by a decrease in the deflection of the galvanometer needle. As the speed of the motor increases this deflection becomes gradually less and less, showing that the back E.M.F. is increasing. As the two machines are identical in construction it would be expected that when the speed of the motor has reached the same number of revolutions per second as that of the dynamo the back E.M.F. would be equal to the E.M.F. produced by the dynamo. As a matter of fact this is impossible, as the friction in the second machine has to be taken into account. Nevertheless, the gradually decreasing galvanometer deflection conclusively proves that a back E.M.F. is set up in the motor coils.

Just another illustration of the power of a machine, such as has been described, to act as a dynamo or as a motor, may be taken.

If a dynamo be used to charge a large battery of accumulators and the prime mover of the dynamo be cut off, the current then flows from the battery, and passing through the coils of the dynamo forces its armature to rotate still in the same direction.

Direction of Rotation.—A careful perusal of the foregoing experiments and diagrams shows that in a shunt motor as described, if the direction of the current through either the field coils or the armature coils be changed, the direction of rotation is changed, but if the direction of the current be reversed through both the field and the armature the two changes have an opposing effect and the armature still rotates in the same direction.

If a back E.M.F. is set up in a motor when rotating, it is obvious that the current passing through the armature must be controlled by the difference between this back pressure and the pressure applied. The actual value in ampères is obtained by dividing the excess pressure in volts by the resistance of the armature in ohms.

Now, wherever energy of one kind is used to produce energy of another kind there is bound to be some energy wasted in the form of friction, heat, etc. In the case of a motor, therefore, sufficient energy must be applied to overcome the amount of mechanical work to be done and to supply the power wasted in doing it.

Speed Regulation.—Now, a motor is self-regulating as regards the amount of power it uses. That is to say, the armature will rotate at the speed necessary to set up such a back E.M.F. that the amount of current controlled by the difference of pressure between the applied E.M.F. and this back E.M.F. is just sufficient to do the work required of the machine. It has been explained elsewhere that the amount of back E.M.F. depends on the rate of cutting lines of force; hence, if the magnetic field be an intense one the armature need only rotate at a slower speed to produce the required opposing pressure than would be necessary if the field were a weak one.

We have here, then, a means of regulating the speed of the motor. If a regulator consisting of a variable resistance be inserted between one of the supply mains and one end of the field magnet windings, the current passing through these windings can be regulated in such a way as to increase or decrease the intensity of the field produced, according to the conditions demanded by the work to be done.

If no mechanical work is being done by the motor—that is, if it is running free—the armature rotates at such a speed as to give a back pressure almost equal to the applied pressure, and consequently the current through the armature is only of a sufficiently small value to provide the energy wasted in the armature, etc., as heat and friction.

When mechanical energy is taken from the motor the speed is slightly reduced, and consequently the back E.M.F. is reduced, thus giving a greater difference between applied and back E.M.F., which is great enough to force the necessary increase in current through the armature, corresponding to the extra driving power required.

The twisting force which makes the armature of a motor rotate is proportional to the strength of the magnetic field and to the strength of the current passing through the conductors that are under the influence of the field.

As the strength of the field depends on the amount of current passing through the field coils, it is readily seen that to start a motor from a position of rest it is necessary

to force a large current through both the field and armature coils. Now the amount of current depends on the pressure, so that it is usual to apply the full available pressure to the field coils when starting.

In the case of the armature we must take another fact into consideration. When it is at rest there is no back E.M.F., and, consequently, if we were to apply the full available pressure to the armature the latter would be short-circuiting the source of supply of current. The current would then be sufficiently strong to injure seriously the windings, as great heat would be produced.

In order to avoid overheating the armature in this way, a resistance is usually inserted in the circuit through which the armature current is flowing, and the resistance is chosen of such a value that when the full available pressure is applied to this resistance in series with the armature, the strength of the current which flows is not much more than the strength of current which flows when the motor is running and the full power is being taken out of it.

Starting arrangements.—In order to understand the starting arrangements properly a simple theoretical diagram of the connections is given (Fig. 51). One of the

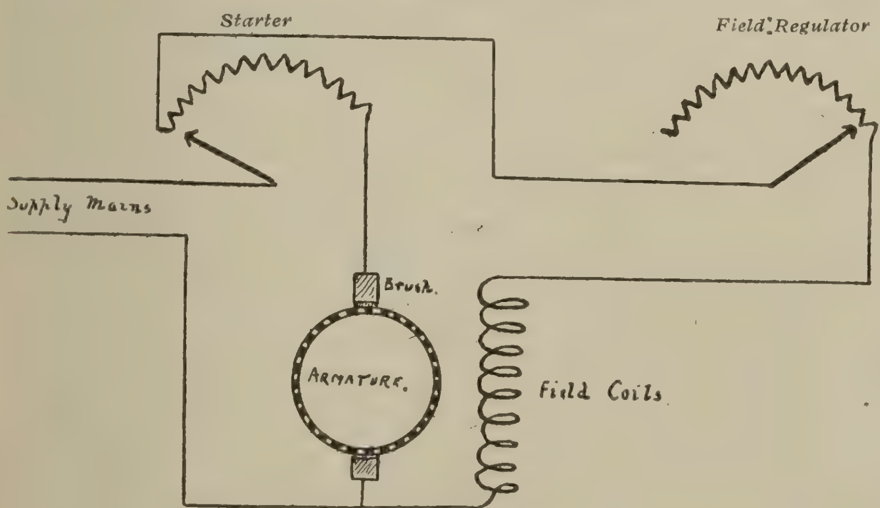


Fig. 51.—Theoretical Sketch of Motor Connections.

supply leads is connected to the pivoted end of the starting resistance regulator. The end of the resistance, with which the other end of this regulating handle

first makes contact, is connected to one end of the field magnet winding, and the other end of the resistance is connected directly to one of the brushes resting on the commutator. A common lead is finally brought from the other end of the field magnet winding and the other commutator brush back to the return supply main. Where a field regulator is used, it is inserted between the end of the resistance first making contact with the regulating handle and the first-mentioned end of the field magnet windings, as in the diagram. Connections are made from different points of the resistance to brass studs, over which the end of the regulating handle moves.

When the handle is moved on to the first stud the field current is a powerful one and the armature current is of a strength dependent on the resistance of the starting resistance together with the resistance of the armature as explained.

The armature now begins to turn until it has acquired a speed capable of producing the back E.M.F. necessary to regulate the armature current to the strength required to drive the motor at a constant speed. The handle is now moved over to the next stud, and because the current through the armature now increases the motor speeds up until once more the two E.M.F.'s become of the values necessary for the maintenance of a constant speed. This process is repeated until finally all the resistance has been cut out, after which the motor is ready for work. Reference to the diagram shows that as the resistance is cut out of the armature circuit it is introduced into the field-magnet circuit. The resistance of the field-magnet winding is, however, much greater than the resistance of the starter, so that the field current is only slightly affected by this introduction. As a matter of fact, in the machine used in standard Marconi sets, the connections are such that the resistance is again cut out of the field circuit when the handle finally comes to rest on the last stud. The actual connections will be given later when dealing with the particular apparatus employed.

No-volt Release.—If the magnetising current be suddenly cut off when the machine is rotating at a high rate of speed there will be no setting-up of a back E.M.F. The result would be a great rush of current through

the armature and a consequent burning of the conductors. In order to provide against the risk caused by an accidental cutting off of this current, a small electro-magnet is inserted in the field circuit in such a position that it exerts a sufficiently strong attractive power over a small piece of iron carried by the regulating handle to hold the latter in position on the final stud, against the force exerted by an antagonistic spring also connected to the handle. This electro-magnet loses its power of attraction as soon as the current ceases to flow through its winding, and the handle is released, and under the action of the antagonistic spring flies back to its original position, thus also cutting off the current through the armature coils and causing the motor to come to a standstill.

Of course, such an interruption of the current through the field circuit, and continuation of the current through the armature circuit, only takes place when a break occurs in the former circuit. This electro-magnetic release, or no-volt release as it is usually called, also prevents an accident of another kind. If the handle of the starter were fixed in its final position by means of a hook or catch of some description, it would remain in this position even if the supply of driving current were cut off from, say, the engine-room. Now, if the supply were to be suddenly switched on again from the engine-rooom, it is seen that it would be equivalent to starting the motor under conditions which it has been explained must be avoided. That is to say, it would be the same as trying to start up with too strong an armature current, and disastrous results would follow.

Over-load Release.—In large machines another electro-magnet is often inserted in the main circuit in such a position that if the current becomes too strong for the safety of the machine, the no-volt release is short-circuited and the driving current thus switched off. This will be more fully described later.

Dynamos and motors are specially constructed according to the current and voltage which they are required to produce or use. If, then, we have current at, say, 100 volts pressure and desire to use current at 300 volts, it is an easy matter to arrange for a motor driven by current at 100 volts to drive a dynamo constructed to deliver

current at 300 volts. Of course a certain amount of power would be lost in the arrangement, as electrical energy is first converted into mechanical energy and the resulting mechanical power reconverted into electrical power. Such an arrangement of a dynamo and motor coupled together mechanically is called a motor-generator.

Rotary Converter.—Now, it has been stated that the currents induced in the armature of a dynamo are commuted into continuous currents by means of the commutator. Most ship's dynamos are constructed on this principle. For wireless telegraphic purposes we often require the original alternating current, and some means have to be adopted to reconvert the commutated current back to its original state. For this purpose a machine called a rotary-converter is usually supplied.

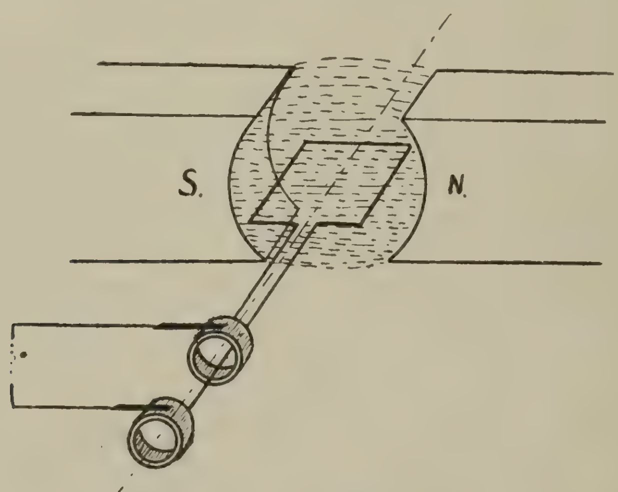


Fig. 52.—Use of Slip Rings.

In Fig. 52 it is seen that two complete rings have taken the place of the commutator shown in Fig. 45. If the two brushes connecting the external circuit be placed one on each of these rings the current in the external circuit is also of an alternating character. In a type of generating machine called an alternator such rings are provided instead of the commutator.

The rotary-converter is fitted with both these arrangements—namely, a commutator and a pair of slip-rings.

Direct current from the ship's dynamo is brought to the commutator end of the armature and is used to drive

the machine as a motor. Tappings are taken from the armature coils to the slip-rings, and when an external circuit is joined across these rings alternating current is forced through it. Figs. 53a and 53b illustrate the

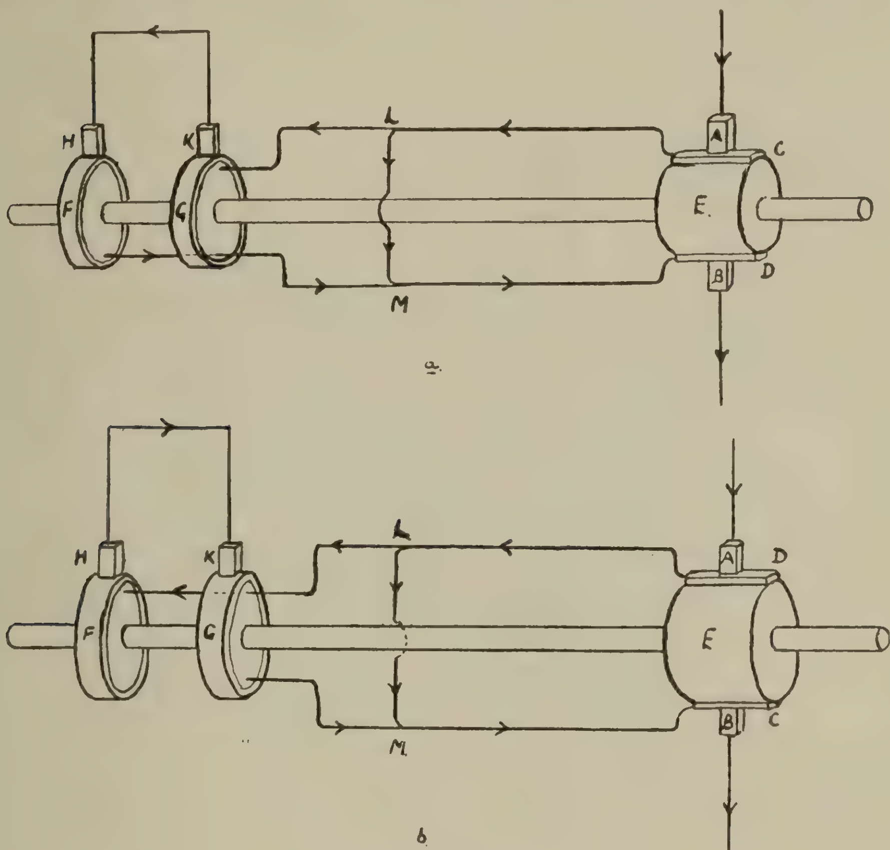


Fig. 53.—Conversion of DC to AC.

arrangement in a simple way. The same lettering is used in each Fig. A and B are two carbon brushes making contact with the bars, C and D, of the commutator, E; F, and G are two slip-rings, with which the carbon brushes, H and K, are making contact. From the points L and M on the armature coil, CLMD, tappings are taken to the slip-rings. Now, when C is vertically above D, as shown in Fig. 53a, and if the current enters at the brush A, a portion will pass through the armature coil, CLMD, and be used to drive the armature round. If an external circuit be joined between H and K, it will be in shunt with the part LM of the coil, CLMD, and consequently a certain current, depending for its value on

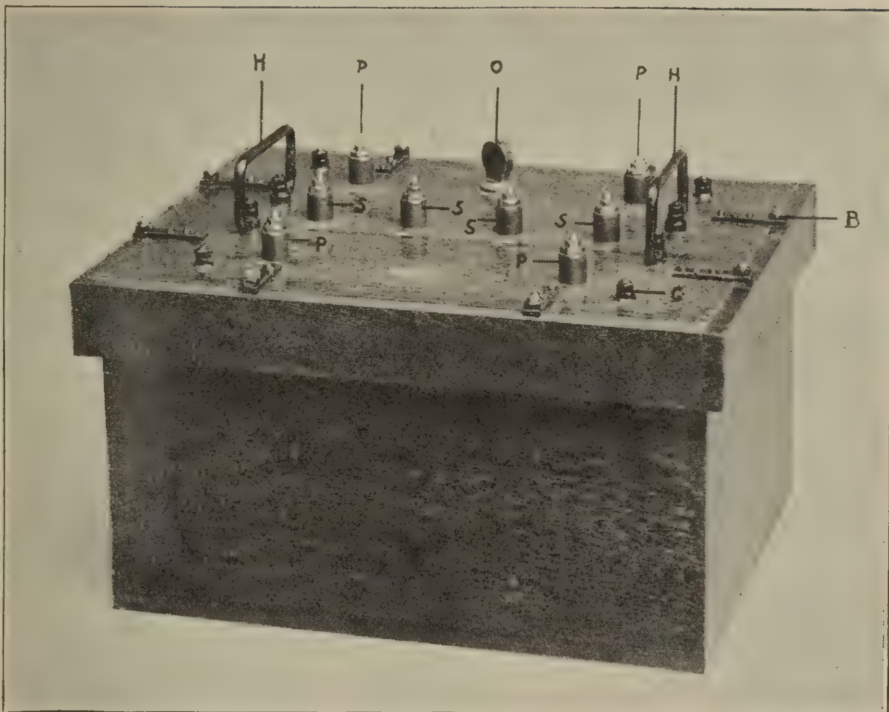
the resistance of the external circuit, will pass through it. The direction of the current through the various parts of the armature and external circuits is shown by means of the arrow-heads, and in Fig. 53a it is seen that the direction in the external circuit is from K to H. After the coil has passed through half a revolution, however, the position of the commutator bars C and D with respect to the brushes A and B has been reversed. The slip-rings have also turned through half a revolution, the whole arrangement being mounted on the shaft XY; and by following the arrow-heads indicating the direction of the current it is seen that the direction through the external circuit is now from H to K. Thus in one complete revolution of the armature of such a machine, which is a two-polar machine, we have a complete cycle of alternating current

The actual rotary-converter supplied with a Marconi standard ship's set ($1\frac{1}{2}$ kw.) is supplied with four field poles, and the arrangement of the armature windings and tappings is such that two complete cycles of alternating current are produced per revolution. Thus, if the machine is driven at a speed of 1,800 revolutions per minute the number of cycles per second is

$$\frac{1800 \times 2}{60} = 60$$

A brass plate is usually affixed to the framework of the machine with the following data (amongst other data)— 50 — 60 $\sim$, indicating that the machine delivers alternating current at 50 to 60 cycles per second, according to the speed at which it is being driven.

Transformers.—A piece of apparatus similar in construction to the induction coil already briefly touched upon may be used in connection with alternating current Two coils of wire may be so arranged that an induced current may be set up in the secondary at either a higher or a lower voltage than that of the primary current. No primary-circuit breaking device is necessary, as in the case of the direct-current induction coil, because, as has been pointed out, the value of an alternating current is continuously changing, and therefore if such a current be used in the primary winding a continuously varying intensity of the magnetic field is taking place. It will be



1½ K.W. TRANSFORMER.

B, Bolts for fixing lid to container.—C, Bolts for holding coils in position.—H, Iron lifting handles.—O, Wooden plug for oil inlet.—P, Primary winding terminals.—S, Secondary winding terminals.

seen that there are four variations of cutting during one cycle of current. A gradual increase in one direction, a decrease in the same direction, an increase in the opposite direction, and a decrease in the same direction as the last increase.

If there are more turns in the secondary winding than in the primary, the secondary voltage will be higher, and the transformer is called a step-up transformer. If the primary has more turns than the secondary, the latter voltage will be lower, and the transformer is called a step-down transformer. A part of the primary may be tapped off to form the secondary, in which case the arrangement is called an auto-transformer. As in the case of the induction coil, an iron core is used to concentrate the magnetic field. In some cases the arrangement of the two coils is identical with that of the induction coil, when the transformer is said to be of the open-core type (Fig. 54a). Another type of transformer is, however, often used in

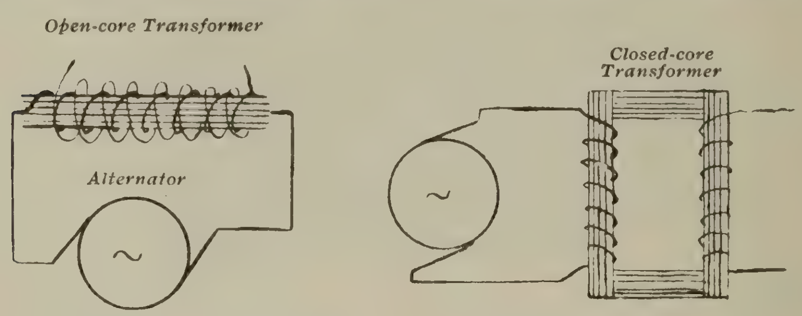


Fig. 54.—(*a*) Open-core Transformer. (*b*) Closed-core Transformer.

which the core forms a continuous circuit, the primary being wound round one part of it and the secondary round another part, as in Fig. 54b. This is known as a closed-core transformer. The open-core type is used in the lower power sets of wireless apparatus and the closed-core type at high-power stations. The secondary current induced is of an alternating nature.

CHAPTER VIII.

INDUCTANCE.

Inertia—Self-induction—Inductance—Mass—Velocity—Acceleration—Experimental proof of inductance—Lenz's law—Measurement of inductance—Henry—Micro-henry—Analogy between mechanical and electrical inertia.

Inertia.—It is now necessary to consider a very important property possessed by all circuits in which an electric current is flowing. This is the property of self-induction, or, as it is more briefly called, "inductance."

The method adopted in most text books to explain this property is to show the analogy that exists between it and mechanical inertia. A brief explanation of what is meant by mechanical inertia is therefore necessary.

When a man jumps on to a 'bus travelling at a high rate of speed he is conscious of having to grip tightly to the rail and feels a strong strain on the arms. After a little while he can relax the grip and maintain a footing on the vehicle without any difficulty. It is seen, therefore, that his body offers some resistance to an increase in the rate of motion from a walking or running pace to the pace of the 'bus. Again, if a man drops off the 'bus when it is travelling at a high speed he must run a little way or otherwise be thrown to the ground. From this we see that his body offers some resistance to a change from the high speed of the 'bus to the lower speed of walking.

Again, we know that a strong force is required to bring a heavy vehicle from a position of rest to a state of motion, but after the vehicle has once begun to move it only requires a small force to maintain this motion. If the force be suddenly removed, the vehicle does not immediately come to rest, but, unless brakes be applied, continues to move for some time. If some obstacle is placed in its way, disastrous results may ensue.

Now, the property in virtue of which a body resists any

change of motion is called its inertia. A law showing the relationship between the motion, mass of a body, and the force required to overcome this inertia is very easily found.

If a mass of one pound be allowed to fall from a height, the force of gravity is the only force applied to it causing its motion. It is found experimentally that such a mass falls 32·2 ft. during the first second after it has been released. During the second second it is found to fall 64·4 ft., and during the third second it falls 96·6 ft. We thus see that its speed is increased or accelerated at the rate of 32·2 ft. per second per second. The force exerted on the mass by gravity is equal to the mass, and in the present case is a force of one pound. If, then, a force of one pound will accelerate a mass of one pound at the rate of 32·2 ft. per second per second, a force of one pound would only accelerate a mass of 32·2 pound at the rate of 1 ft. per second per second. A mass of 32·2 pounds is called an engineer's unit of mass, therefore we can say that a force of one pound is required to give an engineer's unit of mass an acceleration of 1 ft. per second per second. If, then, we say a body has m units of mass, we easily see that the force required to give it an acceleration of a feet per second per second is otained from the equation—

$$F = ma.$$

Inductance.—It is stated that the inductance of an electrical circuit is comparable with mechanical inertia. The analogy existing between the two is so close that a very similar equation for an electrical circuit can be stated to the one given above.

Before considering the equation, however, it is better to compare an electrical circuit with the 'bus spoken of at the beginning of this chapter.

It has been stated that unit current signifies the passage of unit quantity past any point in a conductor in unit time.

That is to say, that current, instead of being expressed as ampères, may be expressed as coulombs per second; and this may be compared with mechanical motion in feet per second. We have shown that the speed of a 'bus is only gradually acquired on the application of a certain

force. We might expect, then, that the strength of current in a circuit gradually rises on the application of electrical pressure. We have stated that on the force being withdrawn from the moving 'bus it comes gradually to rest after having travelled some distance. We might expect, then, that a current would continue to flow for some time after the electrical pressure has been withdrawn. Finally, we have stated that if a moving 'bus is suddenly stopped by the interposing of some obstacle a smash takes place. We might then expect that if an attempt were made to suddenly stop the passage of a current some analogous display of energy would take place.

In a great number of cases it is very difficult to find any such results. If an electrical circuit supplied with a measuring instrument be suddenly switched on to a source of supply, the needle of a good instrument immediately comes to a fixed position, indicating a steady current. According to Ohm's law this is exactly what should happen, for it states that E.M.F. $= CR$. If the current be suddenly switched off the needle does not usually indicate a gradual falling of current, neither does this sudden stoppage of the current bring about anything resembling a mechanical smash-up in a great number of cases.

In a circuit containing a large electro-magnet, however, the analogy holds good. The current is found to mount up gradually on making the circuit, and on break-

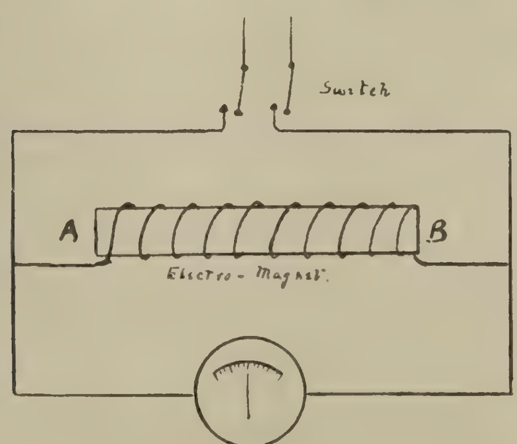


Fig. 55.—Experiment on "Inductance."

ing it suddenly the current still continues to flow. Ordinarily, if a circuit be suddenly broken, there is no path along which it may continue to flow, so that arrangements must be made to provide another path simultaneously with the cutting off of the supply circuit.

Fig. 55 shows a simple arrangement for demonstrating that the current continues to flow even after the supply has been cut off.

Supply mains are connected through a switch to the ends of the winding of an electro-magnet, AB. A galvanometer is joined across the points A, B. When the switch is closed a current passes through the electro-magnet and part of it through the galvanometer, producing a deflection in the latter towards, say, the right. The current passes through the electro-magnet in a direction from A to B. If the switch be suddenly opened, the galvanometer needle is found to be deflected to the left, showing that the current is still flowing through the electro-magnet in the same direction—namely, from A to B—and through the galvanometer from B to A.

Again, the third and final effect is produced in the form of a spark. If the current through a very powerful electro-magnet be interrupted suddenly, a very large spark may take place at the point of interruption, and the current

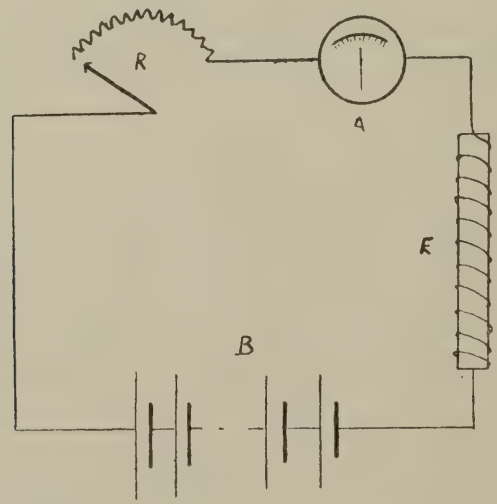


Fig. 56.—Experiment on "Inductance."

continuing through the coil may be at a pressure sufficiently powerful to break down the insulation of the windings unless special precautions are taken. It is usual in the case of large magnet windings to put a resistance across the ends at the same time that the circuit is broken, thus allowing a suitable path through which the current may expend itself.

In order to investigate the conditions governing this action let us consider the accompanying figure (Fig. 56). B is a battery connected through a variable resistance, R, and a current-measuring instrument, A, to an electromagnet, E.

Before any current is passing through the magnet windings no lines of force exist with the exception of those due to the residual magnetism of the core. When the battery is switched on a current flows and increases the number of these lines. It has been stated in a previous chapter that whenever the number of lines of force linked with a conductor is varied, an E.M.F. is induced in that conductor. Therefore, if we gradually vary the resistance R, thus by Ohm's law gradually varying the current through the circuit, we continuously vary the number of lines of force linked with the magnet and produce in the magnet coils an induced current.

Lenz's Law.—Now Lenz experimentally proved that an induced current always tends to stop the motion which produces it. The motion producing this induced current is an increase of the lines of force due to an increase of the current. Therefore we see that the E.M.F. of the induced current is in a direction tending to stop any increase of the original current. If the current be slowly decreased, the number of lines of force is being altered in an opposite sense and the induced E.M.F. is consequently reversed. That is to say, the direction of the induced E.M.F. is such as to prevent the original current being decreased. Now, the rate at which the number of lines of force is being changed depends upon the rate at which the current is changing.

If we so arrange our circuit that a current of one ampère flows during the first second, a current of two ampères during the second second, a current of three ampères during the third second, and so on, we can say

that we have an electric acceleration of one ampère per second. This can be further expressed as an electrical acceleration of one coulomb per second per second, and it is seen to be very similar to our expression for the acceleration of mass—*i.e.*, one foot per second per second.

Now, the unit of E.M.F., the volt, is by definition the E.M.F. induced in a circuit when the number of lines of force linked with it changes at the rate of one hundred million, or 10^8, per second.

If we suppose a circuit in which a current of one ampère produces 10^8 lines of force linked with it, we can say that a current accelerating in it at the rate of one coulomb per second per second is causing an increase of lines of force at the rate of 10^8 lines per second.

This increase is plainly setting up an opposing E.M.F. of one volt, therefore we may say that a pressure of one volt must be applied to the original current to overcome this back pressure in order to allow the current to accelerate at the rate stated. Such a circuit, in which a change of current of one ampère causes a hundred million additional or fewer magnetic lines to be linked with it, is said to have a unit coefficient of self-induction, or unit inductance. The unit of inductance is called the Henry.

Now if the current in a circuit is accelerating at more than one ampère per second, the back or opposing E.M.F. will be correspondingly greater. We can express this by saying that the force required to overcome the back E.M.F. is proportional to the rate of acceleration. Again, if the circuit is of such a type that the rate of increasing of the lines of force is greater than 10^8 for an acceleration of one ampère per second, the induced back E.M.F. will be still further increased and a corresponding increase will be required in the applied E.M.F. to overcome it. We can express this by saying that the force required to overcome the back E.M.F. is proportional to the rate of increase of lines of force per unit acceleration. But this rate of increase of lines of force divided by 10^8 gives us the inductance of the circuit; therefore we can say that the force necessary to overcome the back E.M.F. set up in a circuit by a constantly varying current through it is proportional to the electrical acceleration and to the

inductance, or, if a represents acceleration in coulombs per second per second and L represents the inductance of the circuit, then the force required is: $F = La$.

This we see is very similar to the equation for the force required to overcome mechanical inertia due to mass and mechanical acceleration.

The inductance of a circuit depends on its shape and on the presence of iron in it, as these factors have a determining influence on the number of lines linked with a circuit.

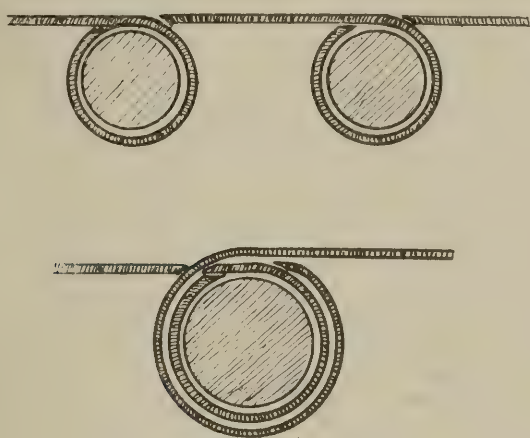
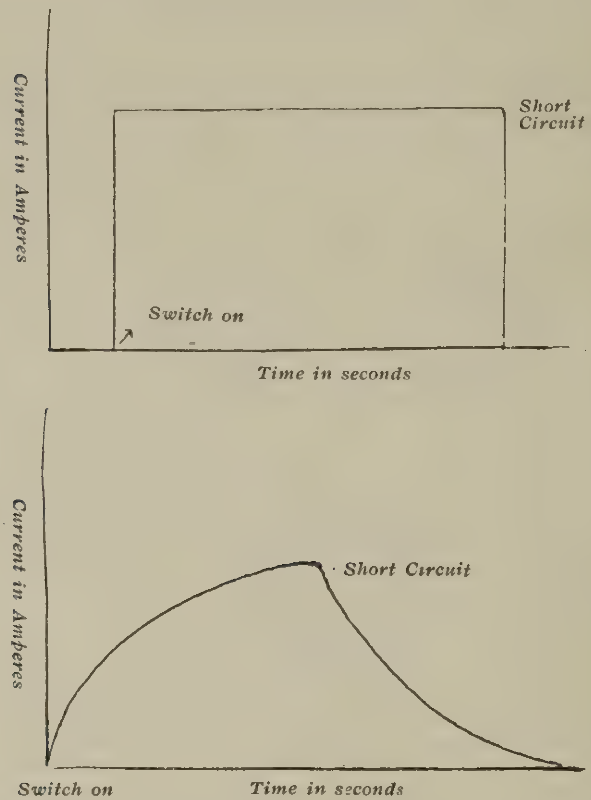


Fig. 57.—Linkages of Lines of Force with a Circuit.

In Fig. 57 a length of wire is given one turn round each of two pieces of iron. If a current be passed through the wire, it is seen that the number of linkages is twice as great as it would have been had the wire only been taken round one piece of iron. If the wire is taken twice round one piece of iron each turn is linked with twice the number of lines and therefore we have four times the linkages, so we see that if n turns of wire are taken round a piece of iron in which N lines are set up by one turn a total linkage of n^2N lines is formed. This is the reason that the effects of inductance in a circuit containing a large electro-magnet are so strongly marked.

Curves showing the difference between the currents in two circuits, one containing an electro-magnet and the other without, are given in Figs. 58a and 58b. Where a

continuous current is concerned the effects are only produced at the starting and stopping stages. When dealing with alternating currents, however, the current is con-



Figs. 58 (*a*) and 58 (*b*). Current Curves in Non-Inductive and Inductive Circuits.

tinuously accelerating either in a positive or negative sense, and consequently the effects are considerable. More will be said on the subject of inductance later.

CHAPTER IX.

DIRECT AND ALTERNATING CURRENT MEASUREMENTS.

Current measurements—Direct current—Voltmeter—Ammeter—Arrangement of instruments in a circuit—Alternating current—Root mean square value—Application of Ohm's law to alternating currents—Impedance—Reactance.

MECHANICAL power is reckoned in foot-pounds per second. So electrical power may be reckoned in volt-coulombs per second. But since one coulomb per second is one ampère, electrical power is measured by the product of ampères and volts. Thus, there is unit power in a circuit when one ampère is flowing at a pressure of one volt. The unit of power is called the watt. For practical purposes a larger unit is used equal to 1,000 watts and called a kilowatt. The kilowatt is approximately equal to $1\frac{1}{3}$ horse-power, one horse-power being 550 foot-pounds per second.

In order to find the power of a circuit it is necessary to know the ampèrage and voltage, and instruments known as ampère-meters (or ammeters) and voltmeters are used to indicate these values.

The Voltmeter.—Mention has already been made of the galvanometer as a means of detecting the presence of a current. If a dial be placed underneath the deflecting needle, it may be calibrated to show by a direct reading the value of the E.M.F. in any circuit. If resistances be placed in parallel in any circuit, the current through each part is inversely proportional to its resistance. That is to say, the greater the resistance the smaller the current. If two conductors be placed in parallel in a circuit, one being of low resistance such as the main conducting wire of a circuit, and the other being of high resistance such as a galvanometer coil or multiplier, the portion of the current passing through the latter is very small. By Ohm's law the current is directly proportional to the E.M.F., so that the potential difference between the two points at which the parallel circuits are connected deter-

mines the amount of current passing. If the P.D. be doubled the current is doubled. But it has been pointed out that any increase of strength of the current passing through a multiplier increases the deflection of the needle; consequently an increase of potential difference will cause an increased deflection. A galvanometer suitably calibrated may therefore be joined in shunt across any two points of a circuit to indicate the difference of potential between them, and such an instrument is then called a *voltmeter*. Many different forms of voltmeter are manufactured, and a great many devices are introduced for such purposes as increasing the sensitiveness or for bringing the indicating needle to rest quickly.

Usually the resistance of the meter is not sufficient, so that additional resistance is added in series.

For details of the various types the operator is referred to any of the numerous text-books which have been written on the subject. The chief point to remember about the voltmeter is that *it is always joined in shunt* and only takes an extremely small portion of the current to operate it.

A small key or switch is often used in connection with a voltmeter in order that it may be put in circuit when required. The connections of the instrument to the circuit are shown in Fig. 94. A, and B, represent two points on a circuit between which it is desired to measure the P.D. A is connected directly to one end of the voltmeter coil, while B is connected to the other end only when the key, K, is depressed.

The Ammeter.—Because this instrument is designed to measure the total current flowing in a circuit, it must be of dimensions large enough to take the whole current and must be inserted in the main circuit. It also depends upon the same principle as the galvanometer, but in this case the coil of wire must be of low resistance. It is therefore constructed of thick wire of a few turns. Ammeters designed to measure heavy currents usually have a copper bar in parallel with the coil, so that only a fixed percentage of the current passes through the latter. When the instrument has been once calibrated the same low resistance bar or shunt must, of course, always be used across the coil. It is usually found advantageous to provide

some means of short circuiting an ammeter, as this is the best way to cut it out of circuit. Fig. 94 shows the means adopted. A and B are two brass blocks connected respectively to the ends of the ammeter coil. The two mains of the circuit are also connected to these blocks, and when the instrument is not in use a brass plug is inserted between the blocks, a path of much less resistance being thus afforded for the main current.

It has been stated that the value of the current and E.M.F. in an alternating current is continuously changing. The instruments for measuring the values of direct current are therefore unsuitable for use with alternating current.

Root Mean Square.—The heat produced in a conductor is proportional to the square of the current and to the effective resistance of the conductor. A means of finding out the value of an alternating current is thus afforded. A direct current may be passed through a known resistance and the amount of heat generated may be measured. If an alternating current be passed through a conductor of the same effective resistance and the heat be measured, a comparison of the two results will give a comparison of the effective values of the squares of the two currents, and the square roots of these values will give the ratio between the values of the currents. The effective value of ampères and volts of an alternating current, following the sine law, is found to be 70·7 per cent. of the maximum values; thus if a sinusoidal alternating current reaches a maximum pressure of 100 volts, the effective, or virtual, value, as it is called, is 70·7 volts. The virtual value of the current and E.M.F. is called the root-mean-square-value because it is the square root of the mean of the squares of all the instantaneous values of the alternating current.

Measuring instruments are designed to give direct readings of the virtual values of alternating current, but it is not proposed to give constructional details, as such information may be obtained from other text books. The ammeter and voltmeter supplied with a standard Marconi set are of this type, and the conventional sign used to represent alternating current (*i.e.*$\sim$) is invariably marked on the dial of such instruments.

Application of Ohm's Law to Alternating Currents.

In a direct current circuit we have seen that $C = \frac{\text{E.M.F.}}{R}$.

In an alternating current circuit account has to be taken of the inductance, because the E.M.F. has to overcome the back E.M.F. of inductance in addition to the resistance.

In an alternating current circuit of inductance L, in which a current of I virtual ampères is flowing at a frequency of n cycles per second the back E.M.F. is equal to $2\pi nLI$ virtual volts. This back E.M.F. is at its greatest value when the current is increasing at the greatest rate, namely, at the moment it is rising from zero value, and is at its smallest value when the rate of change of the current is lowest, namely, when it is at its maximum value. It is thus seen that the back E.M.F. follows a curve exactly one quarter period behind the current curve.

The triangle ABD, Fig. 59, may represent the following dimensions:—

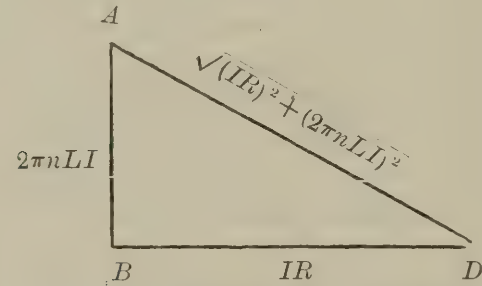


Fig. 59.—Determination of Impressed E.M.F.

BD represents the electro-motive force required to overcome the resistance, which by Ohm's law is equal to the product of the current and the resistance. This can be written RC.

BA represents the force required to overcome the back E.M.F. due to inductance which has already been given as $2\pi nLI$.

The line AD then represents the total impressed E.M.F. necessary to overcome both resistance and inductance.

The value of this line is, of course, equal to the square root of the sum of the squares on the lines AB and BD.

Therefore AD, or the impressed E.M.F., equals $\sqrt{I^2R^2+(2\pi nLI)^2}$, and Ohm's law for an alternating current circuit becomes

$$\text{Virtual ampères} = \frac{\text{Virtual Volts}}{\sqrt{(R)^2+(2\pi nL)^2}}$$

The denominator is usually called the impedance of the circuit, the part due to inductance alone being called the reactance.

CHAPTER X.

Condensers.

Condenser—Capacity—Dielectric—Specific inductive capacity or dielectric constant—Leyden jar—Farad—Micro-farad—Calculation of capacity—Series or cascade arrangement—Parallel arrangement—Proof of formula used for calculation of capacities in series—Condenser compared with spring—Compared with hydraulic circuit.

In the first chapter it was shown that certain bodies could be charged with electricity, and some were stated to be positively charged whilst others were said to be negatively charged.

This property possessed by certain bodies of holding a charge of electricity is made use of in the construction of a piece of electrical apparatus called a condenser.

The main discovery was made by German scientists long ago. At a time when electricity was looked upon as a fluid a certain scientist, whilst attempting to collect some of this fluid in a bottle, received a very nasty shock. He half-filled a glass jar with water, into which he placed a metal chain to be used as a conductor between an electricity-producing machine and the water. When he considered the water sufficiently highly charged he attempted to remove the chain with one hand whilst holding the jar with the other. The jar then discharged a current through his body, producing the shock mentioned.

After this many experiments were made, but a conception of the working of a condenser may be easily obtained without entering into the details of these.

Whenever a positive charge is given to any body a negative charge of equal value is created at some other point.

When two bodies are charged with electricity of the same sign a force of repulsion is manifested between

them, just as a force of repulsion exists between two like magnetic poles. Again, two bodies charged with electricity of opposite signs are found to exercise a force of attraction between each other. This force of attraction and repulsion is exerted through substances which do not allow a passage of electricity through them. Thus, if a sheet of glass be placed between two oppositely charged bodies these bodies are still found to attract each other. In Fig. 60 A and B are two brass discs and C is a sheet

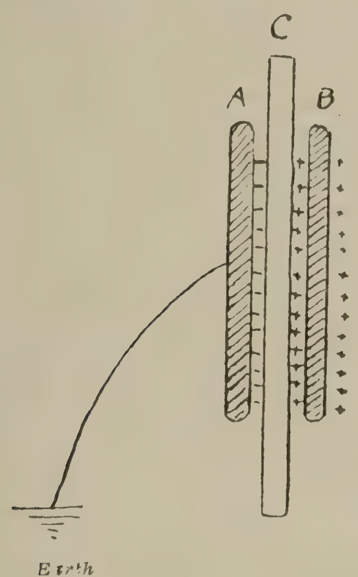


Fig. 60.—Action of Condenser.

of glass placed between them. If a positive charge be given to B positive electricity will be repelled to earth from A, if the latter be connected by means of a conductor to earth, leaving a charge of negative electricity on it. This negative charge attracts the positive electricity on B to the face of the disc nearer the glass, and a further positive charge may be applied to it. We thus see that an arrangement of this kind is capable of holding a greater charge than either of the two discs taken separately, and hence such an arrangement may be called an electrical condenser.

If a charged body be brought near an uncharged body the latter is found to be oppositely electrified at the part nearer the charged body and similarly electrified at the part most remote from it.

If the electrified body be removed the second body

loses this electrification. Such electrification is said to be due to electro-static induction. Lines of force radiate from a charged body just as they have been shown to radiate from the poles of a magnet.

Specific Inductive Capacity.—Some substances seem to offer an easier path for these electro-static lines of force than others. It is found that when a sheet of glass is placed between two conductors the arrangement is capable of holding a greater charge than when air alone separates them. In order to compare the relative capabilities of different materials in this respect the "specific inductive capacity" (as this quality is called) of any material is compared with that of air, which is always taken as unity. Thus, if glass is stated to have a specific inductive capacity (or dielectric constant, as it is sometimes called) of six, we understand that the capacity of a condenser in which glass is used to separate the two plates is six times that of a condenser of equal size, but using air as the separator. The capacity of a condenser is the amount of electricity necessary to raise the difference of potential of its two terminals from zero to unity—that is, to raise its potential through one volt.

Capacity.—A condenser is said to be of unit capacity when a charge of one coulomb causes a difference of potential of one volt between its terminals. The unit of capacity is called the "farad," but as this is much too large for practical purposes a smaller unit, called a "micro-farad," is used. This is one-millionth part of a farad.

The capacity of a plate condenser may be proved theoretically and experimentally to be equal to the area of the plate multiplied by the dielectric constant and divided by 4π times the distance between the plates when the condenser is of such a type that the distance between the plates is very small compared with the area, or—

$$C = \frac{\text{Area in sq. cms.} \times s}{4\pi t}$$

where t equals the distance between the plates in centimetres and s equals the dielectric constant.

The capacity given by this formula is in electro-static

units and must be divided by 900,000 to reduce it to micro-farads.

Leyden Jar.—The best known form of condenser is the Leyden Jar. This consists of a flint glass jar coated for about one-third of its height on its inner and outer surfaces with tinfoil. The mouth of the jar is fitted with a wooden stopper, through which a conducting rod, with ramifications at its end, passes to make connection with the inner coating. The upper end of this rod is usually fitted with a brass ball or terminal. A number of such jars may be joined in either parallel or series in a similar manner to a battery of cells. When a number of jars are connected in parallel it is merely equivalent to increasing the area of the plate, and consequently a total capacity equal to the sum of the separate capacities is obtained. When a series arrangement is made (sometimes called a cascade arrangement) the operation is equivalent to increasing the distance between the plates, and a smaller total capacity results.

Calculation of Capacity.—The calculation of the total capacity of separate capacities in series is found from the following rule. The reciprocal of the total capacity is equal to the sum of the reciprocals of the individual capacities, or

$$\frac{1}{K}=\frac{1}{K_1}+\frac{1}{K_2}+\frac{1}{K_3}+\frac{1}{K_4}\text{ etc.}$$

This equation may be proved as follows:—

Fig. 61 represents n jars connected in cascade or series.

The outer coating of the first jar is connected to the inner coating of the second, and so on throughout the

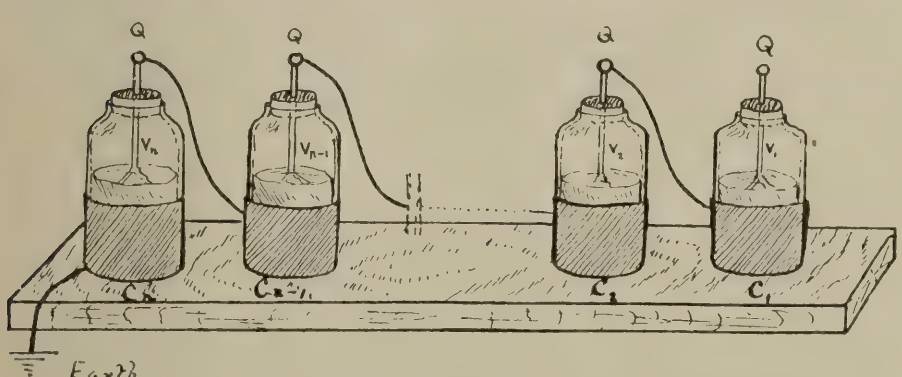
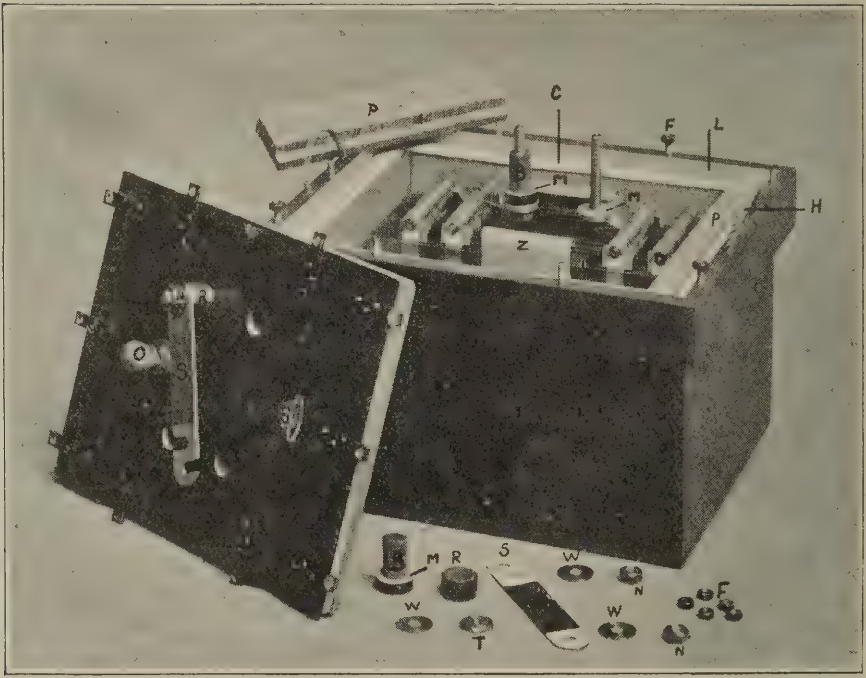


Fig. 61.—Capacity of Series Battery of Leyden Jars.



HALF-PLATE CONDENSER (OPEN).

B, Ebonite bush.—C, Chamois leather pad.—F, Iron nuts for holding lid in place.—H, Rope lifting handles.—L, Lead lining.—M, Thin leather washers.—N, Hexagonal brass nuts.—O, Wooden plug for oil inlet.—P, Cork packing pieces.—R, Ebonite rings.—S, Brass connecting straps.—T, Thin nuts.—W, Brass washers.—Z, Zinc cradle.

series. All the jars except the last have their outer coatings as well as their inner coatings insulated. The outer coating of the last jar is connected to earth.

Suppose a charge Q be given to the inner coating of the right-hand jar.

This charge Q attracts or induces a negative charge, which can be written $-Q$ on the outer coating of the first jar, and repels a charge Q to the inner coating of the second, and so on throughout the system. Thus the charges of all the jars are the same.

Let the potential of the inner coating of the first jar be V_1, and the potentials of the successive inner coatings of the other jars be V_2, V_3, V_4 . . . . V^n, and let the capacities of the respective jars be K_1, K_2, K_3 . . . . K_n.

If C is the number of coulombs displaced through a condenser when the potential difference between the plates is one volt, we shall have V times that displacement when V volts are applied on account of the proportionality of quantity to pressure. But we have seen earlier in this chapter that C is numerically equal to K, the capacity.

Therefore the quantity in coulombs is equal to the product of the capacity and the voltage to which the condenser has been raised by a charge, or—

$$Q = KV.$$

From this equation we obtain a series of similar equations in connection with the cascade arrangement.

The potential of the first jar is equal to the difference of potential between its inner coating and the inner coating of the second jar because the latter is connected to the outer coating of the first.

Therefore, because

$$Q = K_1(V_1 - V_2)$$

$$(V_1 - V_2) = \frac{Q}{K_1}$$

and in a similar way

$$(V_2 - V_3) = \frac{Q}{K_2}$$

$$(V_n - O) = \frac{Q}{K_n}$$

the latter potential being obtained because the potential of the outer jar is zero, as it is earth connected.

The sum of all the right-hand sides of these equations is equal to the sum of all the left-hand sides. Adding them all together, then we get

$$V_1 = \frac{Q}{K_1} + \frac{Q}{K_2} + \frac{Q}{K_3} + \frac{Q}{K_4} + \frac{Q}{K_5} \cdots\cdots \frac{Q}{K_n}$$

or

$$V_1 = Q\left\{\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \frac{1}{K_4} \cdots\cdots \frac{1}{K_n}\right\}$$

But if K be the total capacity of the system

$$V_1 = \frac{Q}{K}$$

Substituting the value of V_1 in the last equation we get

$$\frac{Q}{K} = Q\left\{\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \frac{1}{K_4} \cdots\cdots \frac{1}{K_n}\right\}$$

Dividing each side by Q we finally get

$$\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \frac{1}{K_4} \cdots\cdots \frac{1}{K_n}$$

which it was desired to prove.

Action of Condenser.—A simple way to understand the action of a condenser is to compare it with a spring, and, as in the case of inductance and inertia, it can be shown that the equation showing the relationship between the force and displacement of a spring is very similar to the equation showing the relationship between the force and electrical displacement of a condenser.

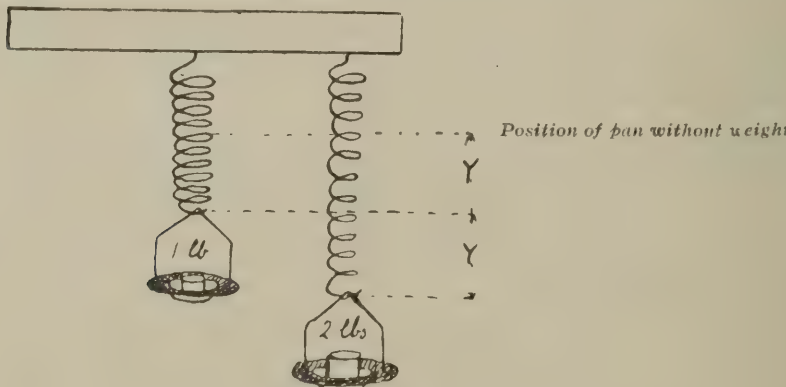


Fig. 62.—Condenser explained by Analogy with Spring.

Fig. 62 shows a spring carrying a pan at its lower end and attached to a horizontal beam at its upper end. If a

weight of one pound be placed in the pan the spring will stretch through a distance which we will call Y.

It is found that the distance through which the spring stretched is exactly proportional to the force applied.

That is to say, if two pounds are placed in the pan the spring is found to stretch twice the distance that it does with a force of one pound. Y is called the yield constant of the spring.

It can be seen that if a force of F pounds be applied the displacement, which may be represented by the letter s, would be equal to the product of the yield constant and the force applied, or $s=FY$, which may be expressed as:—

$$F=\frac{s}{Y}$$

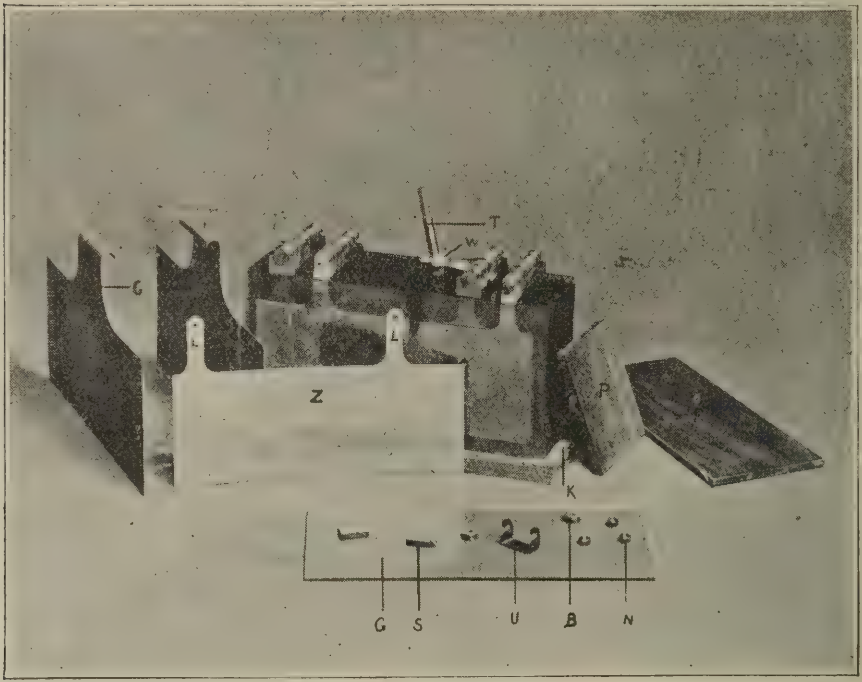
Thus we see that any force applied to a spring is equal to the mechanical displacement divided by a certain constant, which is called the yield constant. In a condenser it has been shown that the electrical force, or voltage, applied is equal to the electrical displacement or quantity divided by a certain constant called the capacity.

The insulating material separating the two conductors of a condenser is called the dielectric. It has been shown that electric influence acts more strongly through glass than it does through air. At the same time it takes a lower voltage to force a current through air than it does to force it through glass, so that, although glass offers an easier path for electro-static lines of force, it offers a higher resistance to the passage of a current. In the designing of a condenser several considerations have to be taken into account.

Thus, if very high pressures are to be used, care must be taken that the insulating properties of the dielectric are sufficiently good to withstand the pressure. If a large capacity is desired the area of the opposing conductors must be considerable.

If large capacity is desired for use with high pressures, it can be seen that the condenser will take up considerable space.

In many cases, however, a large capacity is required for low pressures, and consequently, as the dielectric need only be thin, it is possible to build up a condenser



HALF PLATE CONDENSER PARTS.

B, Brass washer.—C, Zinc cradle.—G, Glass plate.—K, Cork sheet.—L, Lugs of zinc plates.—N, Brass nuts for connecting bolts.—P, Wooden packing pieces.—S, Leather stool.—T, Brass terminal.—U, U-shaped copper strip connection.—W, Thin leather washer.—Z, Zinc plate.

satisfying the conditions which will only take up a small space. Different types of condensers are used in a standard set of apparatus, but these will be dealt with in order as they appear in the different circuits.

A very good idea of the action of a condenser may be gathered from a consideration of Figs. 63 and 64. The

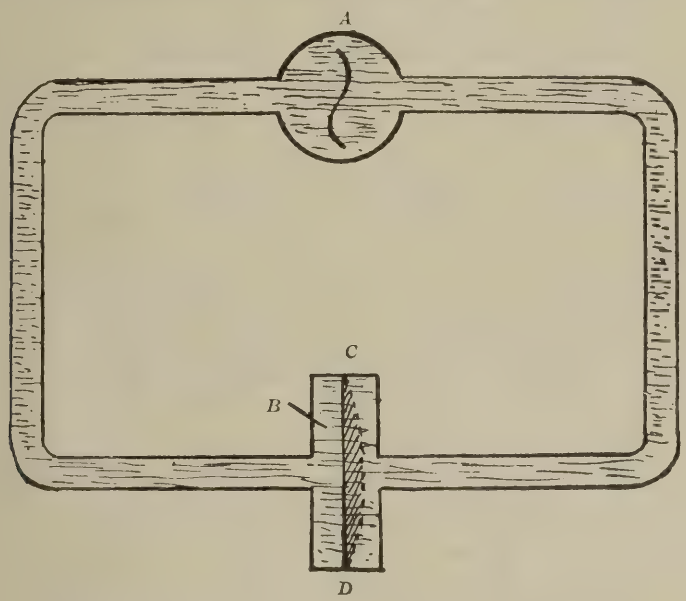


Fig. 63.—Condenser explained by Water Analogy.

first shows a water circuit, in which A is some form of pump, B is a chamber in the circuit, and CD is an elastic partition which is so fixed across the chamber as to prevent the passage of water from one side to the other.

If a force be applied by means of the pump, the elastic partition will stretch and there will be a displacement of water through the circuit, which depends on the amount of "give" in the partition under the applied pressure. If the pressure be sufficiently increased, the partition will break down and the water will then circulate uninterruptedly. It is readily seen that the strength of the partition depends on its thickness and the amount of displacement depends on its area.

In Fig. 64 an electrical circuit is shown in which a condenser, consisting of two metal plates separated from each other by means of a sheet of glass, is connected through a galvanometer, G, to a source of current supply, which may be applied or cut off by means of a key, K.

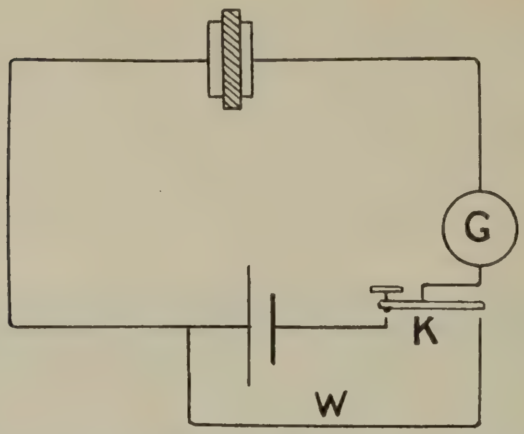


Fig. 64.—Condenser explained by Water Analogy.

Before the circuit is closed the galvanometer needle shows no deflection. On closing the circuit, however, a kick of the needle indicates the passage of a quantity of electricity, which it has been stated depends on the pressure applied and on the capacity of the condenser, which latter in turn depends on its area, dielectric constant, and the distance between the two plates.

If the pressure is increased beyond a certain point the dielectric will be pierced by a spark and the condenser broken down. The dielectric thus corresponds to the elastic partition in the water circuit. Again, if the circuit be made and then broken, at the same time affording a circuit for a condenser discharge through the wire, W, shown in the diagram, the galvanometer needle gives another kick, because a current due to the difference of potential between the two plates takes place through the circuit. In the case of the water circuit, if the force causing a stretching of the elastic partition be suddenly removed, the energy stored up in the elastic (similar to the energy in a spring) forces a flow of water in an opposite direction to the original displacement and equal to it in quantity. Thus the analogy is complete.

PART II.

CHAPTER I.

ELECTRO-MAGNETIC WAVES.

Æther—Wave motion—Elasticity—Inertia—Electro-magnetic waves—Wave motion in water—Wave-length—Velocity—Frequency—Production of æther waves—High-frequency or oscillatory currents—Condenser discharge—Dimensions determining nature of condenser discharge—Resonance—Oscillation constant—Damping—Logarithmic decrement—Wave train—Number of oscillations per train—Spark gap—Plain aerial (P.A.)—Jigger coupling—Resonance curves—Mutual inductance—Co-efficient of coupling—Percentage or degree of coupling.

THE student should now be in a position to apply the information contained in the preceding part of this treatise to the study of wireless telegraphy. Nowadays very few people are ignorant of the fact that wireless telegraphy depends on the production and detection of electro-magnetic waves.

"*Æther.*"—Certain scientific facts have led to the formulation of the theory that all matter is permeated by an imponderable medium, to which the name "æther" has been given. Æther cannot be isolated or detected by any of the senses. The phenomena of light were found to be explicable on the assumption that all matter is permeated by this medium, and because measurements showed that the velocity with which electro-magnetic effects are propagated through any dielectric is the same as the velocity of light, the theory was deduced that æther is the medium through which electro-magnetic energy is propagated in the form of waves.

Wave Motion.—In order that a wave motion may be set up in any medium, the medium must possess the property of elasticity and it must possess inertia of some sort.

When we speak of an elastic substance we mean a

substance which has the power of resisting any change of state produced in it, and in which a stress is produced by any force tending to produce such a change which on the removal of the force brings it back to its original state.

By inertia, as explained under the chapter on inductance, is meant the property of any matter in virtue of which it tends to resist any change of motion.

Thus, if the force producing a stress in an elastic body be removed, a certain motion takes place as the body is returning to its original state. This motion does not cease immediately the body has arrived at its exact original state, but by virtue of inertia continues a certain way, thus producing a state of compression where originally a state of rarefaction had existed. This over-reaching of the state of equilibrium continues for a certain time until the energy supplied by the original applied force is all frittered away.

Æther is a medium possessing such elasticity and inertia, and we must now consider what is meant by wave motion through such a medium.

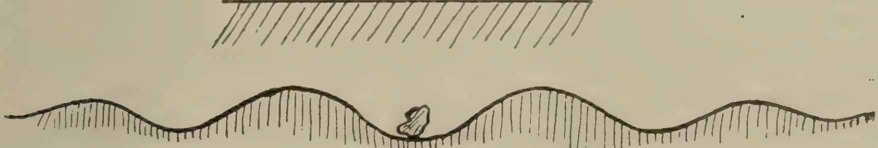
A true conception of the real form of wave motion can only be acquired by the aid of advanced mathematical reasoning, as the relationships existing between such dimensions as time, velocity and different forces, where such dimensions are constantly varying according to fixed laws, are of a highly complicated nature.

It is found convenient, therefore, to compare electro-magnetic wave motion, which, of course, is not made evident to any of the senses, with some form of wave motion which can be seen. Probably every text book on wireless telegraphy gives a description of wave motion through water as a means of explaining æther wave motion, and therefore because it seems to be such a popular method use is once more made of it here.

When any solid body is thrown into water ripples are set up in the form of gradually increasing circles concentrically arranged round the point at which the body enters the water. The ripples nearest this point are very strongly marked, but as the distance from this point increases they become less and less prominent, until finally, if the surface of the water be large enough, they die away altogether. To an observer it almost appears

as though water were being transferred from the centre outwards in the form of a current, but if a piece of floating material be placed on the surface of the water within the influence of the waves it is immediately seen that such is not the case. Instead of the floating body being carried outwards on what appears to be a current it merely rises and falls, at one moment appearing on the top or crest of a ripple and the next moment appearing in the hollow or trough between this ripple and the next. It is thus seen that although there has been no actual transference of matter from the centre of the disturbance to the outermost ripple, some form of energy has been propagated through the medium of the water.

The explanation is as follows:—When the body is thrown into the water it immediately causes a depression of the water under it. The water thus displaced exerts a pressure on the water immediately adjacent to it, with the result that this is also displaced. The only direction in which this adjacent water can be displaced is an upward one, because of the incompressibility of the great mass of water all round it. After the body causing the first displacement has come to rest the originally displaced water returns to its former position. It does not, however, come to rest immediately on reaching this former position, but by virtue of its inertia oversteps the original level. At the same time, the adjacent water is going through the reverse of its first movement. Now, if we imagine the whole water affected as being a great number of very small particles, we can say that the wave motion consists of the motion in an upward and downward direction of each particle, the motion being transferred from each particle to the next in a horizontal



Figs. 65a and 65b.—Production of Wave Motion in Water.

direction. Figs. 65a and 65b roughly show what takes place. The shaded part shows the water and the unshaded part the air above it.

Wave Velocity and Frequency.—Now the outermost visible ripple does not appear simultaneously with the dropping of the body in the water, and we see therefore that the wave travels at a certain speed. The speed of wave motion through any medium depends on the square root of the ratio between the elasticity and the density of the medium.

Now the distance between the crest of one wave and that of the next is called the wave length, and it is clear that if, say, one hundred waves appear during the first second after the disturbing force is applied, the distance through which the first wave has travelled will be equal to one hundred times the length of one wave. Now this distance, having been travelled in one second, is the velocity of the wave. Hence if v represent the velocity, n represent the number of waves per second, and λ represent the length of each wave, λ being the Greek l and pronounced lamda, we may express the relationship between the three quantities as

$$v = n\lambda$$

Now the number of waves per second is called the frequency of the wave; consequently we say that the velocity equals the frequency multiplied by the wave length.

It has been experimentally proved that the velocity of electro-magnetic waves is the same as the velocity of light, which may be taken as 186,000 miles per second, or, roughly, three hundred million metres per second. Thus if the wave length or frequency of a wave be known it is easy to calculate the unknown value.

Production of Electro-Magnetic Waves.—In the chapter on the dynamo the sine curve was briefly dealt with. Such a curve represents what is known as a simple harmonic motion, and as an electro-magnetic wave has simple harmonic motion it can be represented by a sinusoidal curve.

It was explained that one complete reversal of direction of alternating current is called a cycle or period. The number of such cycles or periods per second is called the frequency or periodicity of the particular alternating current dealt with. When the frequency is of the order of one or two hundred per second the current is called a

low frequency current. When it is of the order of one thousand per second it is called a high frequency current. Currents can be produced, however, which alternate at a frequency of hundreds of thousands or millions per second. Such a current of extremely high frequency is usually called an oscillating current. This last type of current is utilised for the production of electro-magnetic waves.

The construction of a machine capable of generating a large amount of power at such a high frequency is at present a matter of great difficulty, and consequently other means have had to be adopted. The method adopted in the Marconi and several other systems of wireless telegraphy depends upon the discharge of a condenser.

Condenser Discharge.—If a condenser be given a charge and a wire of high resistance be joined across its terminals, a discharging current passes from the positively charged plate to the negatively charged plate, and the condenser is found to be in an uncharged state. The positive and negative electricity have neutralised each other. The form of the current passing through such a high resistance circuit is shown in Fig. 66.

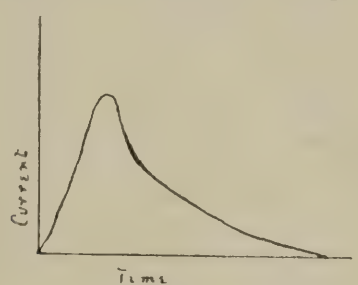


Fig. 66.—Condenser Discharge through High Resistance.

If the experiment be repeated, using a wire of very little resistance in place of the wire of high resistance, the condenser is not discharged by the passage of a current in one direction only. A current flows from the positively charged plate to the negatively charged one, and does not cease at the point of neutralisation, but by virtue of inductance oversteps the mark and gives a positive charge to the plate which was originally negatively charged, leaving a negative charge on the originally positively charged plate. When the force producing this over-

stepping of the point of equilibrium has been overcome, the difference of potential between the two plates is sufficient to force another current in the opposite direction, which current, like the first one, oversteps the point of electrical level. Each change of direction of the current is accompanied by a loss of energy due to the creation of heat, etc., so that in time the energy becomes so small that the backward and forward movement of current ceases altogether. The condenser is then said to have been discharged by means of an oscillating current, and the whole circuit is called an oscillatory circuit. A current thus produced may be represented as a curve as shown in Fig. 67.

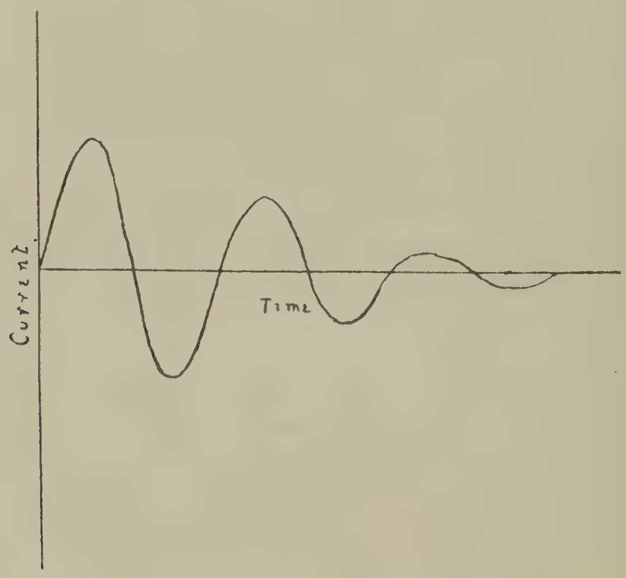


Fig. 67.—Oscillatory Condenser Discharge.

The nature of a condenser discharge is determined by the relations which exist between the capacity, inductance and resistance of the circuit. Let R represent the resistance, C the capacity, and L the inductance, then—

(1) If R is less than $\sqrt{\frac{4L}{C}}$ the circuit will be oscillatory.

(2) If R is greater than $\sqrt{\frac{4L}{C}}$ the circuit will be non-oscillatory.

(3) If R is equal to $\sqrt{\frac{4L}{C}}$ the circuit will be just non-oscillatory.

Frequency.—The number of oscillations per second, or the frequency, also depends directly on these three quantities.

When a circuit carrying alternating current possesses capacity the value of the impedance is further modified and the equation becomes—

$$\text{Virtual ampères} = \frac{\text{Virtual Volts}}{\sqrt{R^2 + \left(2\pi nL - \dfrac{1}{2\pi nC}\right)^2}}$$

The quantity $2\pi n$ is often abbreviated and represented by the letter p, so that the denominator may be written

$$\sqrt{R^2 + \left(Lp - \frac{1}{Cp}\right)^2}$$

That part of the total impedance due to inductance has been called reactance, and the term captance has been introduced to describe the part of the impedance due to capacity. Capacity in a circuit tends to cause the current to lead the E.M.F., and is thus seen to have the opposite effect to that produced by inductance, which has been shown to cause the current to lag behind.

It is plain that the current will assume a maximum value when the denominator is as small as possible. The resistance only would have to be considered if the values of L and C were such that the portion $\left(2\pi nL - \dfrac{1}{2\pi nC}\right)$ were equal to zero.

Again if

$$2\pi nL - \frac{1}{2\pi nC} = 0$$

it is easily seen that

$$n = \frac{1}{2\pi\sqrt{LC}}$$

Therefore, if the last relationship between the frequency, inductance and capacity can be obtained a maximum current will flow in the circuit. In any

oscillatory circuit the quantity $\frac{1}{2\pi\sqrt{LC}}=n$ where n is called the natural frequency of the circuit.

Resonance.—When an alternating or periodic E.M.F. is set up in a circuit and the frequency of this E.M.F. is the same as the natural frequency of the circuit, a much greater current is produced than is produced if the two frequencies do not agree. This effect is said to be due to electric resonance. The frequency of the E.M.F. is said to be in tune or in syntony with the natural frequency of the circuit.

Wave Length.—It has been explained that the velocity equals the product of the wave length and the frequency. Substituting the above value for frequency we are able to obtain an equation for wave length in terms of the inductance and capacity of a circuit, as follows:—

$$\lambda=\frac{3\times10^{10}}{\frac{1}{2\pi\sqrt{CL}}}$$

where λ is reckoned in centimetres, C in farads, and L in henries.

The units used for practical wireless telegraphic purposes are the microfarad, which is one millionth of a farad, and the microhenry, which is one millionth of a henry. When these are used as units, and λ is expressed in metres, the following equation simplifies calculations

$$\lambda=1884{\cdot}96\sqrt{CL}$$

Now from this equation it can be seen that the only factors which really determine the wave length in a circuit arranged for wireless purposes (*i.e.*, without appreciable resistance) are C and L. If either of these quantities be increased a corresponding increase in wave length is effected, and if either be decreased a corresponding decrease in wave length ensues.

Clearly, the increase or decrease of wave length effected by an increase or decrease of C or L is not proportionate to such an increase. If C or L be doubled the wave length will only be increased in the ratio of $\sqrt{2}$.

An increase in C and a proportionate decrease in L

neutralise each other and the wave length remains the same.

The quantity $\sqrt{CL}$ is therefore called the oscillation constant.

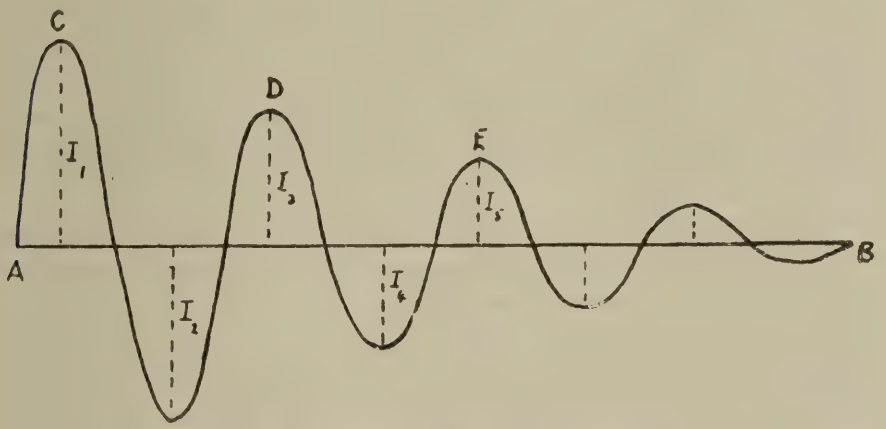


Fig. 68.—Explanation of "Decrement."

Damping.—Fig. 68 shows the curve for an oscillating condenser discharge. The points C, D, E, etc., show the maximum value of the current in each oscillation. These values are called the amplitudes of the oscillations. The whole series of oscillations from the first with a large amplitude, to the last appreciable one is called a train of oscillations or waves, and because the amplitude of each succeeding oscillation is smaller than that of the preceding one such a train of oscillations is said to be *damped*. A train of oscillations of constant amplitude is said to be undamped or persistent.

Now the damping has a very important bearing on the tuning (to be discussed later), and it is necessary therefore to have some means of considering it from a mathematical point of view.

Logarithmic Decrement.—In Fig. 68 the lines I_1, I_2, I_3, etc., represent the maximum amplitudes in each successive half period, and it is found that a fixed ratio exists between any adjacent two, or that—

$$\frac{I_1}{I_2} = \frac{I_2}{I_3} = \frac{I_3}{I_4} = \frac{I_4}{I_5} \text{ etc.}$$

It is also found that this ratio is equal to 2·7183 to the power δ (delta) where δ is a constant for any particular oscillatory circuit.

If then $\frac{I_1}{I_2} = 2{\cdot}7183^{\delta}$, by the definition of a logarithm we see that $\delta = \log_{2\cdot7183} \frac{I_1}{I_2}$

But 2·7183 is the base of the Napierian system of logarithms and is often written ϵ, therefore the equation may be expressed in words as follows:—

Delta is equal to the Napierian logarithm of the ratio between any two successive maximum amplitudes in the opposite direction.

The constant δ is called the logarithmic decrement and is a measure of the damping in any particular circuit.

Some confusion arises from the fact that German writers define the decrement to be the Napierian logarithm of the ratio between two successive maximum amplitudes in the same direction, that is, separated by an interval of one period instead of one half period. In the instrument designed by the Marconi Company for measuring by direct reading the decrement of a circuit, the decrement is understood to be the Napierian logarithm of the ratio between successive maximum amplitudes in opposite directions, as described above.

Number of Oscillations per Train.—Amongst other things the logarithmic decrement is useful for determining the number of oscillations in a train of waves.

Theoretically the oscillations should continue indefinitely, but in practice it may be taken for granted that when the maximum amplitude has fallen to 1 per cent. of the initial maximum, the oscillations may be considered to be damped right out.

Where m equals the number of complete oscillations in a train and δ equals the decrement it may be proved that

$$2m = \frac{\mathrm{Log}_\epsilon \frac{I_1}{I_m} + \delta}{\delta}$$

If, as stated above, I_m has fallen to 1 per cent. of the value of I_1, the fraction $\frac{I_1}{I_m}$ becomes 100, and the above equation may be written

$$2m = \frac{\mathrm{Log}_\epsilon\, 100 + \delta}{\delta}$$

$\mathrm{Log}_\epsilon\, 100 = 4{\cdot}605$.

Therefore, provided the decrement be known, it is easy to find the number of oscillations per train from the formula

$$m = \frac{4 \cdot 605 + \delta}{2\delta}$$

If the decrement of a circuit be large it shows that a great deal of energy is being lost either in the form of heat or by radiation. If R represents the resistance which would give an equivalent loss in the circuit, and if L is the inductance reckoned in equivalent units,

$$\delta = \frac{R}{4nL}$$

It is thus seen that where the resistance of an oscillatory circuit is comparatively great the decrement is proportionately high.

The Spark Gap.—In order to produce a powerful oscillating discharge from a condenser it is necessary to interrupt the continuity of the circuit in order that the condenser may be charged up to a high potential. A small gap is therefore inserted at some part of the circuit, the ends of the wire between which the gap exists being usually supplied with two small spheres. The resistance of air to the passage of electricity is very great, and consequently the condenser is only capable of forcing a discharging current through the circuit when it has acquired a high potential. After the first discharge in one direction the air gap becomes conductive in proportion to the amount of electricity passing. The conductivity is also roughly inversely proportional to the length of the spark, and both these facts must be considered in fixing the size of the gap. If a condenser of small capacity be used a small quantity will charge it to a high potential, and unless a fairly large gap be used the discharge takes the form of an arc. If a large capacity be used a large quantity is required to charge it to a high potential, and if rapid discharge is required the gap must be a small one. With a small gap the resistance is lower, so that an oscillating circuit of large capacity with a small spark gap is desirable for the generation of slightly damped trains of oscillations. Such a circuit is shown in Fig. 69, where C is a condenser and S is a spark gap. A

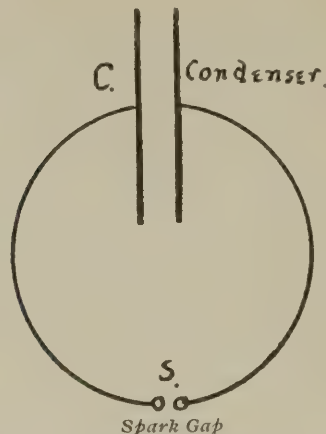


Fig. 69.—Closed Oscillatory Circuit.

circuit of this type does not, however, radiate very strongly. It is known as a closed circuit.

Plain Aerial.—The first form of transmitting apparatus consisted of a circuit of the opposite type. The condenser was of very small capacity, and consequently, as a very high voltage was very quickly set up in it, the spark gap was large.

A long vertical wire called an aerial wire formed one side of the condenser, and the other side was supplied by the earth. As the spark gap was large the resistance of the circuit was comparatively high and the damping great. In addition, a great deal of radiation was given. This type of circuit, therefore, is a good radiator but a poor storer of energy.

Fig. 70 shows this method of producing electro-magnetic waves. AB is the aerial wire and CD an earth connection. Some form of high voltage generator is connected across the spark gap BC. When the voltage of the aerial-earth condenser is sufficiently great to break down the resistance of the spark gap an oscillatory discharge takes place. Before this discharge takes place the energy exists in the form of electro-static lines of force between the two halves of the condenser as shown. Immediately the spark is formed this energy is converted into current energy, which sets up lines of force in the form of concentric circles round the aerial, these electro-magnetic lines being at right angles to the previous electro-static lines. It will be seen that both these forces

are at right angles to the direction in which the waves are radiated or, as it is usually called, the direction of propagation.

It is found that the wave length of this type of oscillating circuit is between four and four and a half times the length of the aerial, but as the decrement is large this type is not used except in certain special cases.

Coupling.—If part of the external connection across the condenser in an oscillating circuit be given the form of a coil of one or more turns, and if this coil have a second coil wound over it, or placed near it, of such a form

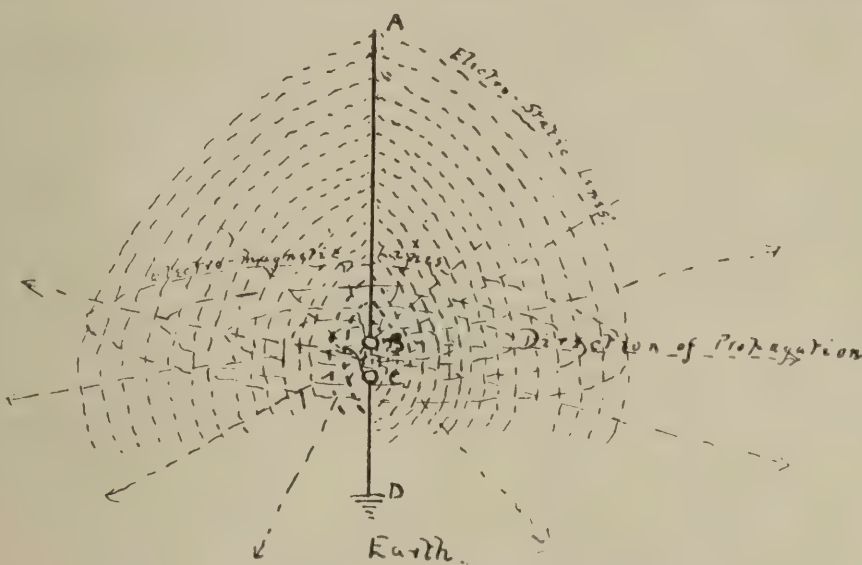


Fig. 70.—Distribution of Lines of Force round Aerial.

as to be capable of carrying an oscillating current, such a current will be set up in it by induction, when the condenser discharges itself.

Such an arrangement of coils is called an oscillation transformer, and the coils are said to be inductively coupled. If the distance between the two is very small they are said to be closely coupled, and if it is great they are said to be loosely coupled. See Figs. 71a and 71b. The coils are called respectively primary and secondary coils, and the secondary may form part of either a closed or an open circuit.

If only one coil be used between two circuits, one part of it may act as primary and another part as secondary. In such a case, where one part is common to both circuits,

the circuits are said to be directly coupled and the transformer is called an "auto-transformer" or "auto-jigger."

Direct coupling is not used in the Marconi system, but is found in the United Wireless sets, which, of course, are now under the control of the Marconi Company.

In the chapter on transformers it was shown that an iron core is advantageously used to increase the intensity of the field. In an oscillation transformer such a core cannot be used on account of the high frequency of the currents and the hysteresis of the iron. The presence of

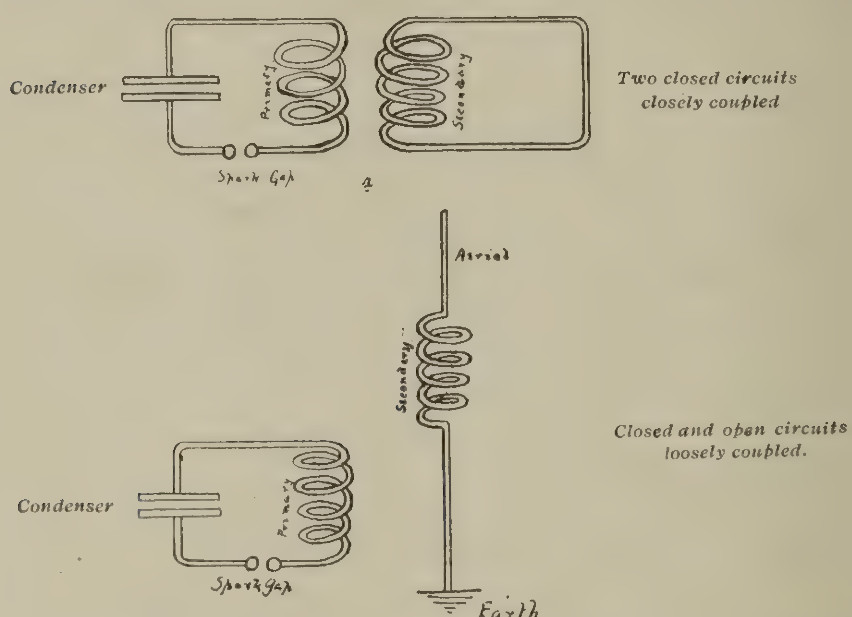


Fig. 71.—(*a*) Closely coupled closed Circuits. (*b*) Closed and open Circuits loosely coupled.

an iron core in an oscillation transformer would give rise to the production of great heat.

If the oscillation constants of the primary and secondary circuits are equal, the current induced in the secondary is very much greater than that induced when the oscillation constants do not agree.

As the oscillation constant is simply a function of the capacity and inductance, it is seen that by introducing either a variable condenser or a variable inductance into either or both circuits the two may be very easily put in resonance.

Again, as the strength of the current induced depends

upon resonance, a measurement of the induced current affords a means of determining when such resonance has been effected. Furthermore, as the maximum current is the determining value, only a comparative measurement need be made.

Thus if an incandescent lamp be shunted across a certain part of, say, the secondary circuit, and the oscillation constant be varied by altering either the capacity or inductance of the circuit, the arrangement which gives the maximum glow of the lamp is that which places the circuits in resonance. Such a lamp is permanently connected in a standard Marconi set, and is called a tuning lamp.

Resonance Curve.—If an instrument capable of actually measuring the current be used, several readings can be taken for different condenser values. A curve may be plotted with the condenser values as abscissæ and the corresponding current values as ordinates, and such a curve may take the form shown in Figs. 72a and 72b. The peak of the curve shows the maximum current, which is called the resonance current. The frequency of the circuit corresponding to the capacity of the condenser producing the resonance current is called the resonance frequency.

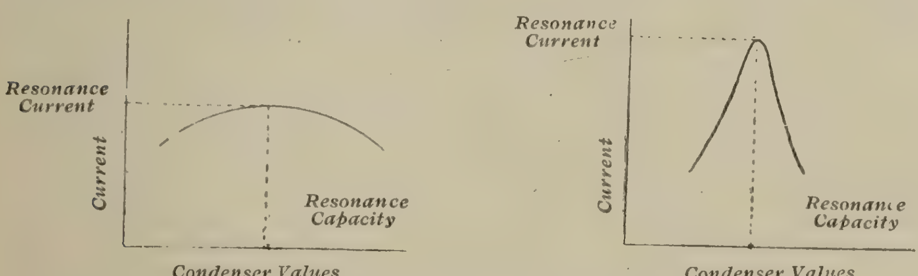


Fig. 72 (*a*) and (*b*).—Resonance Curves.

A glance at the curve shown in Fig. 72b shows that a slight variation of the condenser—either increasing or decreasing its value—causes a considerable alteration in the current produced. In other words, it is seen that here exact tuning greatly increases the current, denoting small energy loss in the circuit, and consequently shows the circuit to possess a small decrement. Fig. 72a. on the contrary, shows that the current is not greatly affected

by tuning, and consequently the energy loss and damping are greater.

Mutual Inductance.—If oscillations in a primary circuit inductively set up oscillations in a secondary circuit, it is logical to suppose that these secondary oscillations will in turn have an inducing effect on the primary, and so on.

The effect produced by the inter-action of the primary and secondary oscillations is said to be due to the mutual inductance of the two circuits. This mutual inductance between two coils may be calculated from the following formula:—

$$M = \frac{L_1 - L_2}{4}$$

where M represents the mutual inductance, L_1 represents the inductance of the two coils joined in series in such a manner that the currents traverse both in the same direction, and L_2 represents the inductance of the two coils joined in series in such a manner that the current traverses them in opposite directions.

It is found, when the coupling of the two coils of an oscillation transformer is very close, that there are two values of the condenser at which a variation on either side produces a decrease in the value of the current. The curve is shown in Fig. 73, and seen to be double humped.

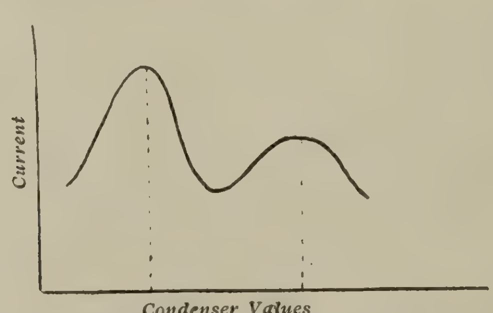


Fig. 73.—Double Humped Resonance Curve.

In such a case where the two peaks are distinct and some distance apart it is possible to measure the decrement of each set of oscillations.

When two distinct wave lengths are emitted it is clear that the prevention of interference is more difficult. By

suitably arranging the coupling, however, a position is found at which practically only one set of oscillations is produced. If a very loose coupling be used the mutual inductance becomes negligibly small and greater selectivity results. Radiation with such a very loose coupling is comparatively weak, as the amount of energy transferred to the secondary is small.

We see, therefore, that where selectivity is the great desideratum a loose coupling is necessary. Where great radiation is required a closer coupling must be adopted even at the expense of selectivity.

Coefficient of Coupling.—The coefficient of coupling is defined as being the ratio between the mutual inductance and the square root of the product of the individual inductances, or,

$$k = \frac{M}{\sqrt{L_1 \; L_2}}$$

where k represents the coefficient of coupling, M the mutual inductance, L_1 the inductance of one coil taken separately, and L_2 the inductance of the other.

Thus, in the case of a transmitting set, L_1 represents the total inductance of the primary circuit (including the leads, the jigger primary, primary inductance) and L_2 represents the total inductance of the aerial circuit, (including aerial, aerial tuning inductance and jigger secondary).

As coupling has an effect on the decrements and frequencies of the oscillations, a true measurement of coupling must be based on some relationship introducing decrement in addition to mutual and individual inductance.

The inclusion of decrements makes the calculation somewhat involved, but as the decrements are so small they can be neglected in the type of coupling used in a standard set.

Percentage or Degree of Coupling.—Coupling is usually reckoned as a percentage of the maximum. Theoretically the closest coupling would be unity, but this is impossible in practice, as inductance in a circuit is not confined to the coil but is spread throughout the circuit. If by calculation or experiment the coupling is found to be ·1

for instance, as this is one-tenth of unity, this coupling may be expressed as a 10 per cent. coupling.

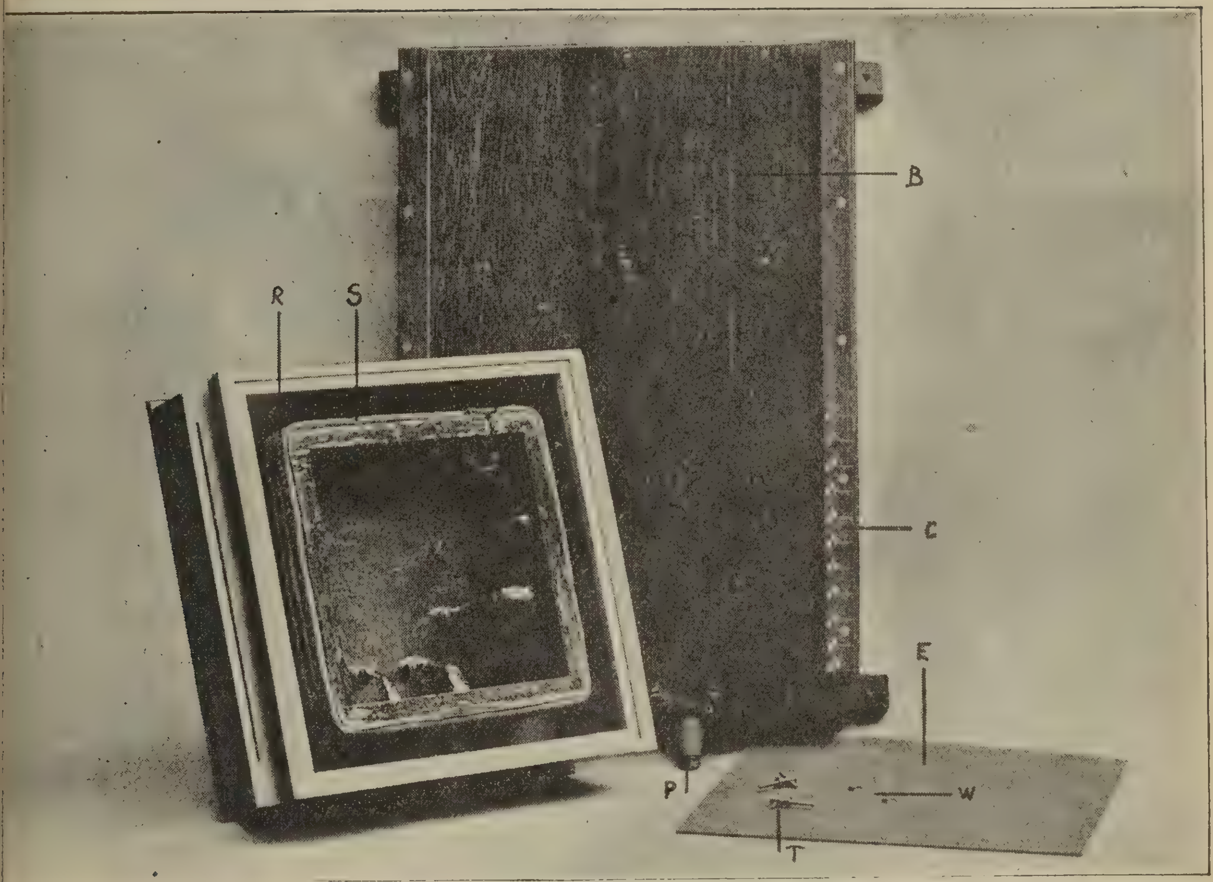
The coupling is most conveniently found from the following formula:—

$$k=\frac{\lambda_1^2-\lambda_2^2}{\lambda_1^2+\lambda_2^2}$$

where k is the coupling and λ_1 and λ_2 the lengths of the two waves emitted, and if λ_0 is the wave-length of each circuit (primary and secondary) separately,

$\lambda_1=\lambda_0\sqrt{1+k}$ giving the longer wave.

$\lambda_2=\lambda_0\sqrt{1-k}$ giving the shorter wave.



TRANSMITTING JIGGER.

Jigger primary casing.—C, Coupling calibration.—E, Ebonite sheet for back of secondary casing.—P, mary terminal.—R, Rope separator.—S, Secondary winding.—T, Brass thumb screws.—W, Brass washers.—X, Ebonite bush.

CHAPTER II.

The Receiving Circuit.

Receiving circuit—Telephone—Detectors—Magnetic detector—Tuning of receiving circuit—Coupled receiving circuits—Resonance curves—Flattening effect of resistance in receiving circuit—Method of increasing selectivity of receiving circuit—Valve detector—Rectifying effect—Resistance of telephones.

The receiving circuit may be looked upon as being the secondary circuit in an extremely loosely coupled oscillation transformer of which the transmitting circuit is the primary.

If two oscillatory circuits consisting in each case of a Leyden jar and an external circuit possessing inductance be taken it is found that a discharge in one circuit will produce a discharge in the other under certain conditions.

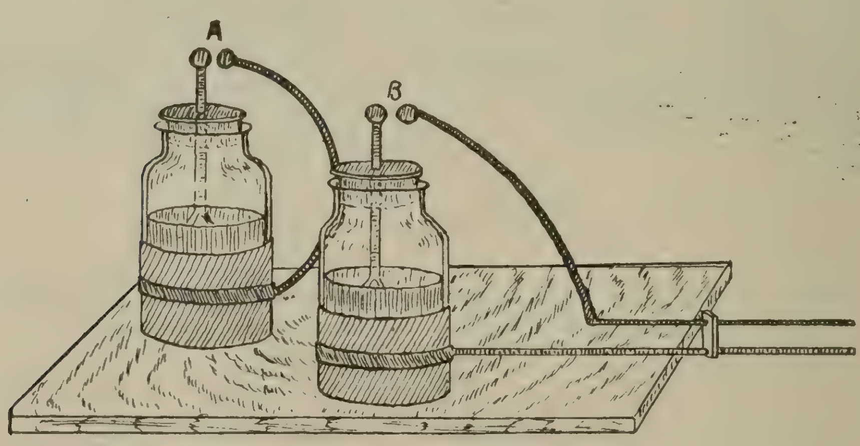


Fig. 74.—Experiment in Resonance.

Two such circuits are represented in Fig. 74. When a discharge takes place across the spark gap A, small sparks

are found to oscillate across the spark gap B, provided the inductance in B's circuit is properly adjusted. The oscillation constant of the two circuits must be the same. This effect may be produced when the two circuits are some distance apart, and is due to the electro-magnetic waves radiated from the first circuit impinging on the second circuit and setting up corresponding oscillations in it. If the distance between the two circuits is great, the energy in the second one is not sufficient to break down the spark gap and no discernible oscillations are set up in the circuit.

The amount of energy in the receiving circuit depends to a great extent on the surface presented to the oncoming waves. It has been explained that an oscillatory circuit consisting of an earthed elevated conductor is a good radiator. At the same time it will be seen that such a conductor presents a great surface on which waves may impinge. Thus an elevated conductor may be used at a wireless station for both transmission and reception purposes. In wireless stations of low power the same conductor or aerial is used for both purposes, but where large power is used it is found that separate transmitting and receiving aerials are required.

If the frequency of such a conductor be the same as that of a distant similar conductor, oscillations in the latter produce electro-magnetic waves which set up oscillatory currents in the former. These oscillatory currents are so very weak, however, that their detection can only be effected by the insertion in the circuit of very delicate apparatus.

The Telephone.—Now the telephone is one of the most sensitive pieces of electrical apparatus known, but as its action is electro-magnetic and dependent upon the variation of the magnetisation of an iron core, the reactance of the telephone coils would be very large, thus preventing the oscillatory currents from passing. Also the telephone diaphragm is unable to keep pace with the extremely rapid changes in the direction of an oscillating current, and in order to use the telephone as a receiver the oscillating currents must be converted into intermittent unidirectional currents.

Even presuming, however, that the telephone could

vibrate in time with the oscillating currents, the vibrations would be at such an extremely rapid rate that they would not be detected as sound by the human ear, which in many cases is unable to hear the comparatively low note of a bat's cry.

Magnetic Detector.—Different devices are adopted for rendering the oscillating currents detectable. The best known method is by means of an instrument known as a magnetic detector. In this instrument a band of stranded soft iron wire is kept moving round two insulated pulleys. This band passes in front of the poles of two permanent horse-shoe magnets. Now the particles of iron become small magnets under the influence of the lines of force, and as the band is moving it has the power to drag the lines of force along in the direction of its motion. As the particles of iron pass from the influence of a north pole to that of a south pole the direction of magnetism is changed. But this change in magnetism does not take place in time with the change in the force producing it. That is to say, the particles do not change their magnetism until some time after they have passed the point where the influence of the opposite pole is being exerted. If an oscillating current be passed through a coil of wire wound round the moving band where it passes in front of the magnets it

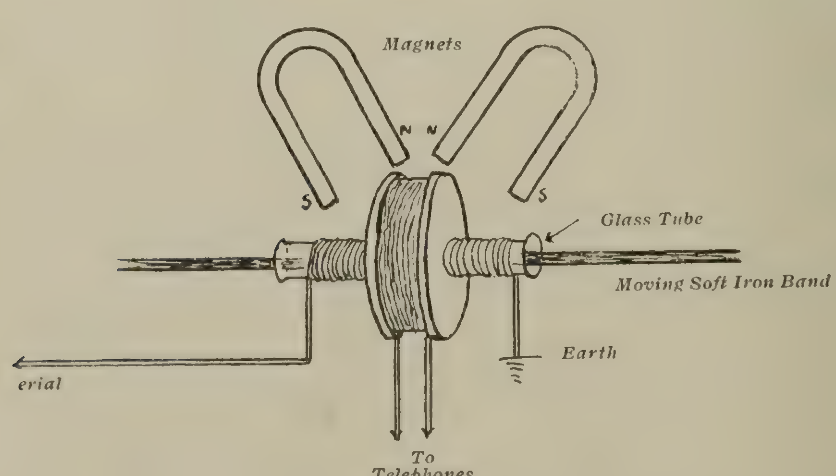


Fig. 75.—Magnetic Detector.

has the effect of causing the lag in magnetism to disappear. Such a coil is wound on a small glass tube as shown in Fig. 75, and the ends of this coil are connected to the elevated conductor and earth respectively.

A second coil of a much greater number of turns is wound over the first and a pair of telephones is connected to its extremities. When the transmitting station sends out a train of waves, oscillating currents are set up in the receiving aerial, which pass through the primary coil and cause a sudden change in the state of magnetisation of the moving iron band. This change induces a current in the secondary, which passes through the coils of the telephone and causes a vibration of the diaphragm. Thus just as long as sparks take place at the sending station, corresponding changes will be taking place in the magnetism of the moving band and the diaphragm will be kept in continuous vibration. If the sparks be made during long and short periods representing dashes and dots of the Morse code, sounds of corresponding duration are heard in the telephones.

Tuning.—A receiving circuit consisting only of an aerial with such a magnetic detector connected between it and the earth would not, however, be of very much use in actual practice. It is necessary to also introduce some means of varying the oscillation constant of the circuit in order to place it in resonance with the frequencies of any particular transmitting station with which it may be desired to communicate. The natural frequency of an aerial depends on its length, which determines its capacity. A decrease in its capacity may be effected by placing another capacity in series with it. Whereas its inductance cannot be conveniently decreased, it may be increased by adding inductance in series. Thus, by placing a variable inductance and a variable condenser in series with the aerial all the necessary means for either increasing or decreasing the oscillation constant are provided. Fig. 76 shows such a circuit. A represents the aerial, C a variable condenser, B a variable inductance, and M the magnetic detector.

Harmonics.—Now, such a circuit would not only respond to oscillations of its own frequency, although such oscillations would produce the maximum effect in it. Oscillations

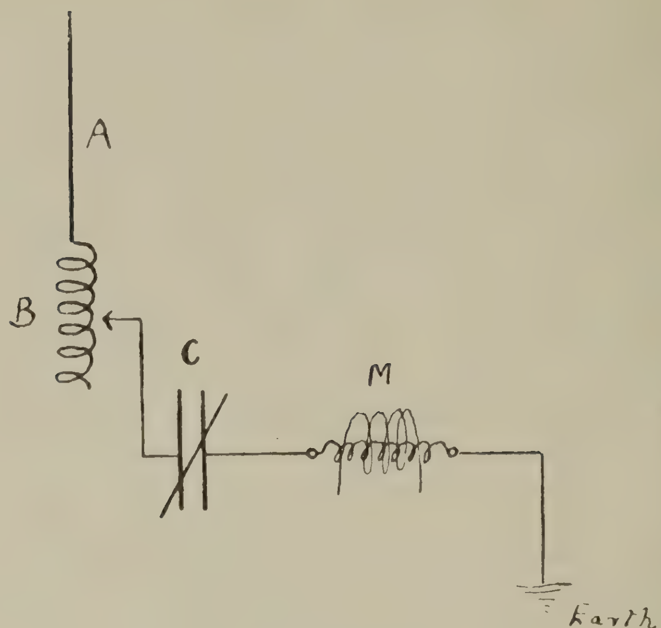


Fig. 76.—Simple Receiving Circuit.

with frequencies of one-third, one-fifth, or one-seventh of its natural frequency would be set up, such oscillations being known as harmonics.

Harmonics are more readily set up in an open circuit of the aerial type than in a closed circuit. Consequently, if a part of the open receiving circuit be used as the primary of an oscillation transformer, the secondary of the transformer can form part of a closed circuit containing the receiving apparatus.

Coupled Receiving Circuits.—This closed circuit, not responding so well to the harmonics of its fundamental frequency, is then better adapted to the elimination of waves other than those required. Such an arrangement of two circuits is shown in Fig. 77. The second circuit must, of course, be supplied with means of tuning it to the open circuit, and a variable condenser is used for this purpose.

As in the transmitting arrangement already described, the coupling between the primary and secondary of the transformer has a certain effect, in so far that oscillations of two frequencies, each one slightly different to the

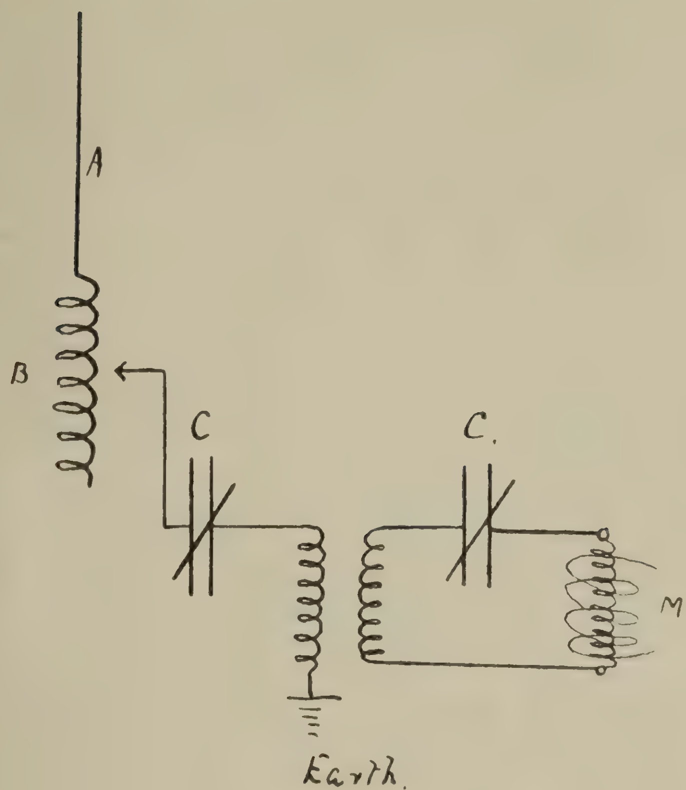


Fig. 77.—Coupled Receiving Circuits.

frequency of the oscillations in the primary, are induced. Thus, if the coupling be a close one, two adjustments are found giving a pronounced increase in the signals compared with any other adjustment. Condenser values corresponding to the two peaks of a double-humped resonance curve are found by trial. The strongest signals are produced when the coupling is such that these two humps are practically indistinguishable, consequently the circuits are so arranged as to admit of variable coupling.

When " standing by " to receive from a station sending on a wave of unknown length a close coupling is used to make the receiver responsive through a wide range of wave lengths. As soon as communication is established the coupling is loosened in order to render the receiver responsive through a narrow range of wave lengths and thus avoid interference from other transmitting stations.

When a circuit is said to be tuned for the reception of a certain wave length, it is understood that the maximum strength of signals is obtained by the reception of that particular wave length. It is found, however, that waves of slightly different length, either longer or shorter, will produce signals in the receiver, which signals are weaker than those from the tuned wave.

We can, therefore, plot a curve showing the relationship between the strength of the received signals and the respective wave lengths. The peak of this curve, of course, denotes the strength of the signals produced by the wave for the reception of which the circuit is in tune.

If the peak rises sharply, as in Fig. 72b, it indicates that the circuit responds only slightly to waves of a different length, but if the curve is a flat one, as in Fig. 72a, it shows that the circuit is responsive to wave lengths varying through a wide range.

Intermediate Receiving Circuit.—It has been said that a closed circuit, not responding so well as an open circuit to the harmonics of its fundamental frequency, is better

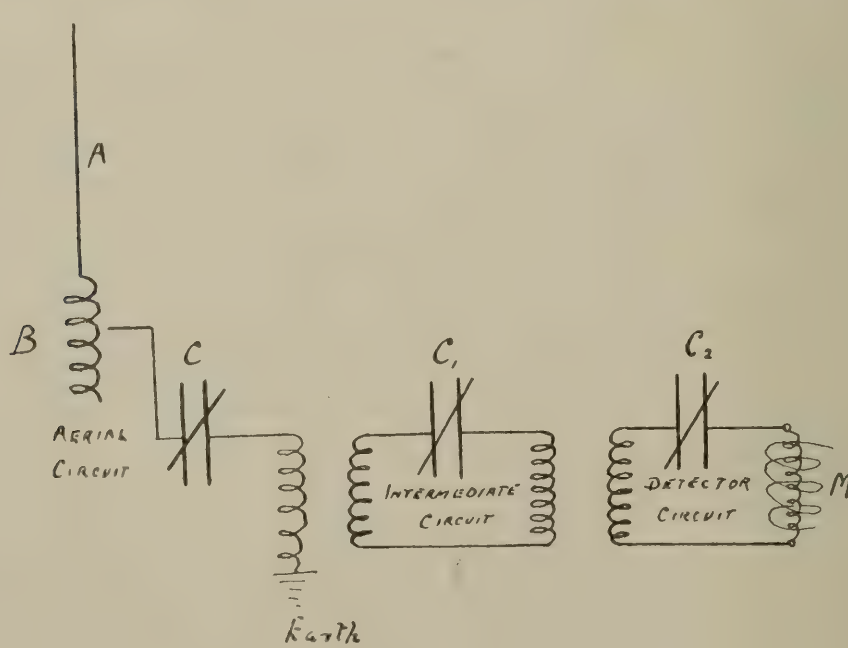


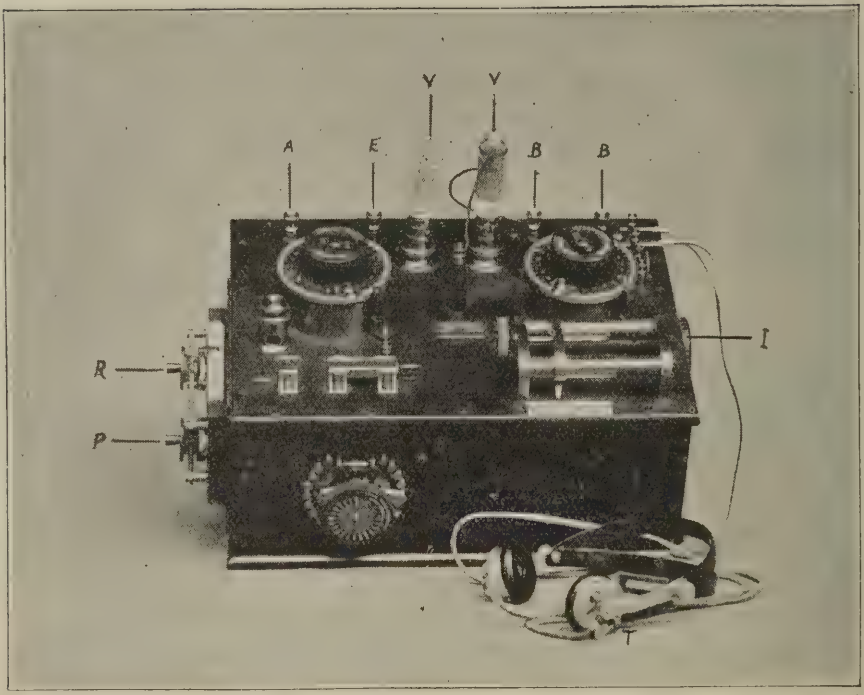
Fig. 78.—Receiving Circuits of Multiple Tuner.

adapted to the elimination of waves other than those required. An extra intermediate oscillating circuit is therefore very often interposed between the aerial circuit and a third circuit containing the detector.

The intermediate circuit contains two coils, one of which acts as a secondary to the primary in the aerial circuit, while the other acts as a primary to the secondary contained in the detector circuit. This arrangement is shown in Fig. 78. The condenser by means of which the intermediate circuit is tuned is placed in parallel with the coils, as it is advisable to preserve symmetry in some cases. The variable capacities and inductances for the three circuits are all contained in an instrument called a multiple tuner. The actual tuner contains other parts, which will be dealt with later when describing the instrument in detail.

The Valve Detector.—Another detector, which is found to be more sensitive than the magnetic detector, is known as a Fleming valve rectifier. This consists of a tungsten or carbon filament lamp in which a cylindrical metal sheath surrounds the filament. It is found that when the filament is incandescent the space between it and the sheath is conductive in one direction. If such a lamp be placed in an oscillating circuit the oscillations are rectified into intermittent uni-directional currents capable of actuating a telephone. Negative electricity is said to pass from the glowing filament to the sheath, and consequently one end of the oscillating circuit is connected to the negative lamp lead and the other to the sheath. The intensity of the glow of the filament has a certain effect on the strength of the rectified current, and consequently a variable resistance is used in connection with the battery from which the current producing incandescence is taken.

It is also found that if an E.M.F. be applied to the valve circuit a more sensitive condition is obtained. A wire of high resistance is joined across the battery supplying current to the valve and a moving contact is connected to the telephones. This resistance is called a potentiometer, because by means of the sliding contact two points may be taken in the circuit between which any desired differ



VALVE TUNER.

A, Aerial terminal.—B, Valve battery terminals.—E, Earth terminal.—I, Intensifier handle. — P, Potentiometer. — R, Valve resistance.—T, High resistance telephones.—V, 4-volt valves.

ence of potential may be arranged. The arrangement of the valve circuit is shown in Fig. 79.

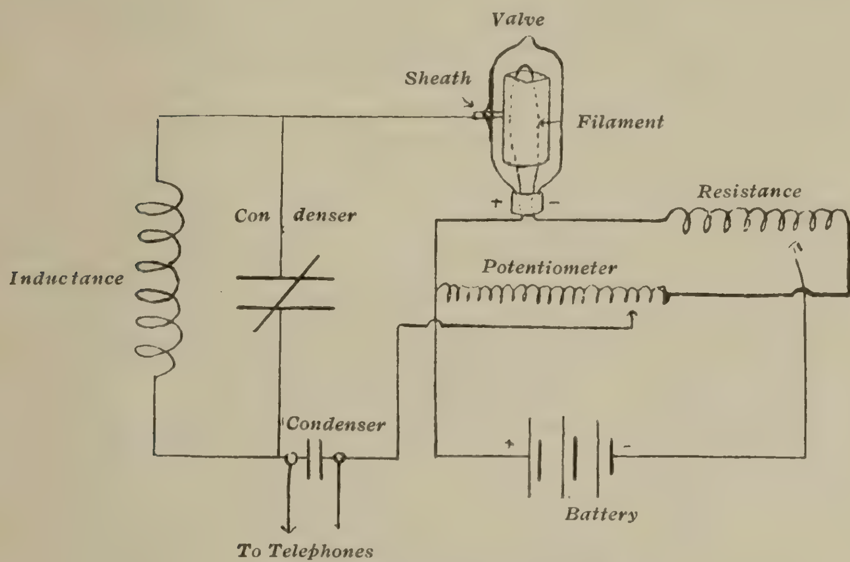


Fig. 79.—Valve Receiving Circuit.

The valve detector is used in connection with various circuits similar to those employed when using the magnetic detector. One important difference should, however, be noted.

Resistance of Telephones.—The telephones used with the magnetic detector are wound to a comparatively low resistance—namely, 140 ohms. This is because the magnetic detector produces a high current effect, and as the sensitiveness of the telephones depends within limits on the ampère turns the maximum sensitiveness is obtained with a comparatively small number of turns.

The valve, however, produces a greater E.M.F. effect, and consequently a great number of turns are found to be advantageous. The telephones used with a valve receiver may be wound to a resistance as high as 8,000 ohms, but a more usual figure is about two or three thousand ohms. If a telephone transformer be used in conjunction with low resistance telephones the same effect is produced. Such a transformer is of the step-down type, the primary winding containing a great number of turns compared

with the secondary, so that a current of lower E.M.F. but greater ampèrage is obtained.

At one time the windings of an ordinary ten-inch induction coil were used for this purpose, but a special telephone transformer occupying much less space and weighing considerably less is now employed.

PART III.

CHAPTER I.

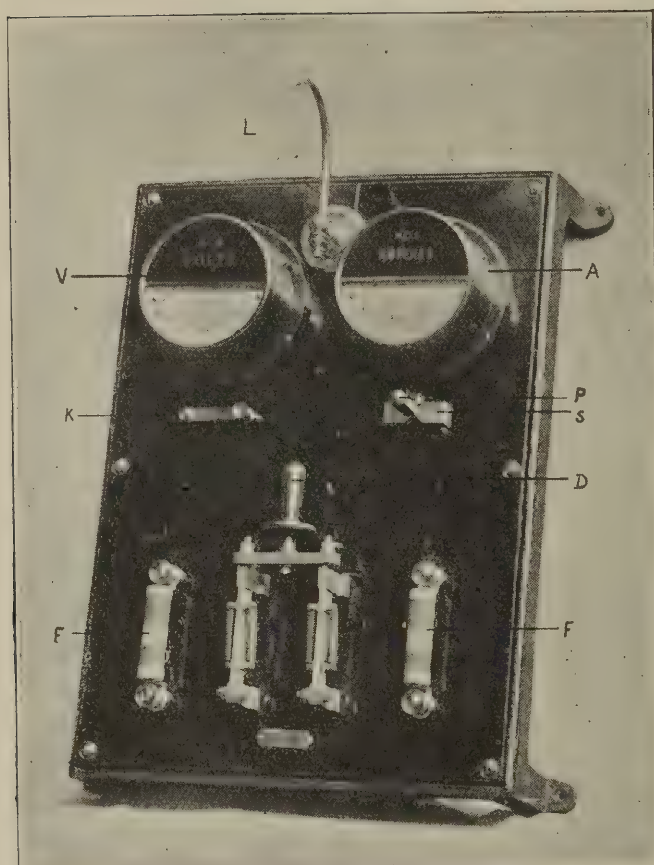
THE $1\frac{1}{2}$ K.W. SET.

$1\frac{1}{2}$ k.w. set—Transmitting circuits—Direct current circuit—Main switch—Starter—Field regulator—Converter—Low frequency primary circuit—Iolanda switchboard—Low frequency iron core inductance—Manipulating key—Magnetic key (single)—Transformer primary—High tension circuit—Transformer secondary—Air core choke coils—Main condenser—Closed oscillatory circuit—Main condenser—Discharger—High-frequency sliding inductance—Transmitting jigger primary—Radiating or open oscillatory circuit—Jigger secondary—Aerial tuning inductance—Earth arrester spark gap—Tuning lamp—Short wave condenser—Receiving circuit—Magnetic detector—Multiple tuner—Disc condenser—Telephone condenser—Telephones—Short-circuiting device—Adjustment of receiving circuit—Measurement of received waves—Measurement of transmitted waves—Emergency apparatus—Accumulator battery—Induction coil—Marine type switchboard—Double coil set.

THE student is now in a position to understand the working of the various parts of a standard Marconi set. This set is most frequently used on board ship, and, of course, depends for its current upon the ship's dynamo. Two main leads are brought into the operating room and connected to a double pole knife switch. From this switch onwards the care and management of the wireless apparatus lies entirely in the operator's hands, and for this reason it is intended to give a full description of each part in the order in which it appears in the different circuits.

TRANSMITTING APPARATUS.

THE DIRECT CURRENT CIRCUIT.—The first circuit to be considered is that used in connection with the driving of a rotary converter. This circuit may be said to con-



A.C. SWITCHBOARD (IOLANDA TYPE).

A, Ammeter.—D, Double pole knife switch.—F, Cartridge fuses.—K, Voltmeter key.—L, Pilot lamp.—P, Ammeter short circuiting plug.—S, Short circuiting plug socket.

tain four pieces of apparatus—the main switch, the starter, the field regulator, and the converter. The main switch is of dimensions large enough to enable it to carry a current of fifty ampères. By dividing each

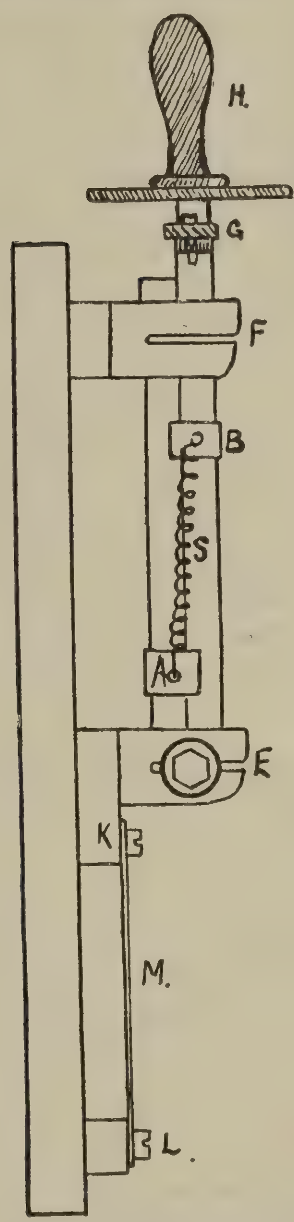


Fig. 80.—Double Pole Knife Switch.

pole piece into two parts and connecting the two parts by means of a spring a means of breaking the circuit quickly is obtained. Fig. 80 shows a side elevation of the switch. A and B are the two halves of one of the

poles, and S is a helical spring joined to each half at A and B. The whole switch is hinged at E, and the upper part, when the switch is closed, fits into the socket F. The upper extremity of the part B is attached by means of screws to an insulating piece, G, to which the handle of the switch H is fixed. When the circuit is being broken the part B comes away from the socket F, leaving the second part A at rest in the socket until the tension on the spring S is sufficient to pull it out suddenly. The brass block K, at which the switch is hinged, is supplied with a nut and washer in order that a fuse wire, M, may be attached between it and the screw L, from which point one of the leads to the converter circuit is taken.

The Starter.—The starter consists of a series of resistance wires contained in an iron case, on the front of which is a slate face fitted with brass studs, no-volt release, starting handle and (in some cases) an overload release. Tappings from the series of resistance wires are brought to the studs on the face of the starter. Fig. 81 shows the connections of a starter which is

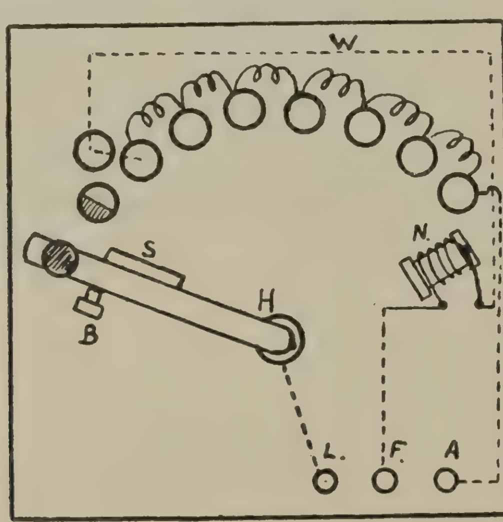


Fig. 81.—Connections of Starter.

generally used in a $1\frac{1}{2}$ K.W. set, and which is not fitted with an overload release. The three terminals marked L, F, and A are connected to "line," "field," and "armature" respectively. An internal connection con-

nects the terminal L with the starting handle H, which carries a small soft iron armature, S, on one side of it. The under side of H is supplied with a spring contact piece, and the first stud is bevelled in order that this spring may be raised from its normal position to make contact with each stud as it slides over it. Another light spring is also attached to the under side of H, carrying at its extremity a piece of carbon, which is the first part of the starter to come in contact with an active stud. A little sparking is apt to take place at this point, and sparking has a less harmful effect on the piece of carbon than on the main contact spring. The first active stud is connected by means of a short straight wire, W, to one end of the no-volt release winding N, from the other end of which a connection is taken to the terminal F. As is seen from the diagram, the first stud is also connected to one end of the series of resistance, the other end being connected directly to the terminal A. It must be mentioned that the connection at N between the first stud and the winding of the no-volt release is also in metallic connection with the soft iron frame or core on which the wire is wound.

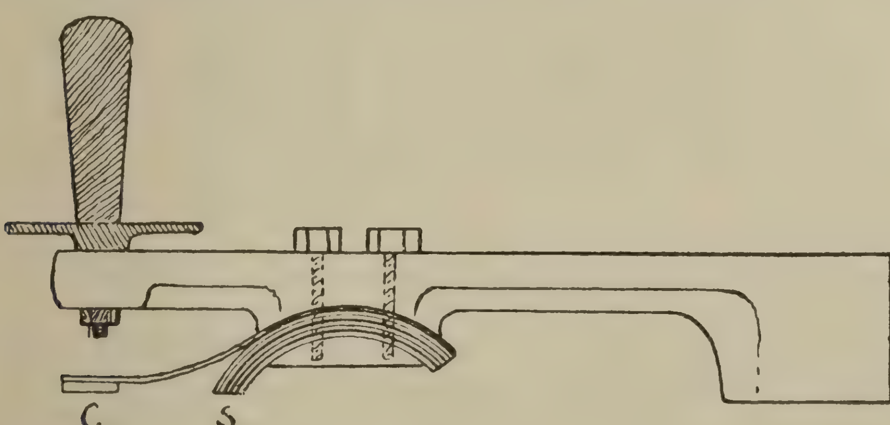


Fig. 82.—Starter Handle.

Fig. 82 shows the starting handle. C is the carbon contact mentioned above and S the main contact spring.

The handle is kept in its normal position of rest by means of a spring contained in the end at which it is pivoted. The tension on this spring may be regulated to a strength suitable to the power of the electro-magnet

of the no-load release. An idea of how this adjustment is made can be obtained from Fig. 83. P is a pin fixed at right angles to the face of the starter, round which the handle turns. A spring, S, is placed over this pin fixed at one end in a small socket, K. The handle, H, fits over this spring. A brass collar, C, in which a small hole, D, is bored to take the other end of the spring, S, is next fitted on the pin, and the whole arrangement is loosely held in place by means of the nut, N, which screws on to the threaded end of the pin. On the face

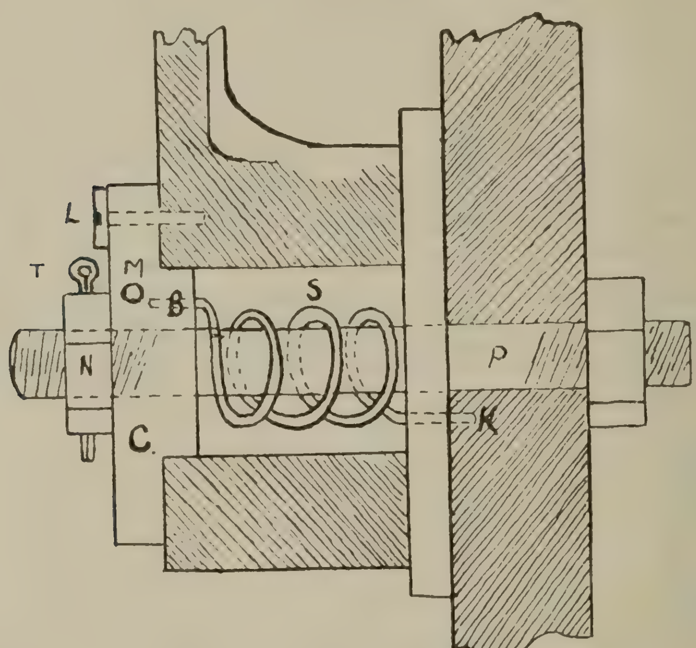


Fig. 83.—Antagonistic Spring in Starter Handle.

of the handle four small holes are tapped to take the screw L, which is seen passing through the collar. By inserting a tommy in the small hole M on the periphery of the collar a certain amount of tension may be put on the spring S, and if the screw L be driven home into the nearest hole on the face of the handle this tension will always be exerted and will keep the handle in a position of rest against the buffer B (Fig. 81), unless a sufficiently strong pull is exerted by the electro-magnetism of the no-volt release during the working of the machine. When the required adjustment has been

made the lock-nut N is tightened up and held in position by means of a split pin, T.

The Field Regulator.—The field regulator is somewhat similar in appearance to the starter. It consists of a series of resistance wires connected to a set of brass studs fixed on the face of a slate slab. The first and last studs are respectively marked "in" and "out." Two terminals are supplied at the base of the slate face, the left-hand terminal being connected internally to the pivoted end of the regulating handle, and the right-hand terminal being connected internally to the last stud

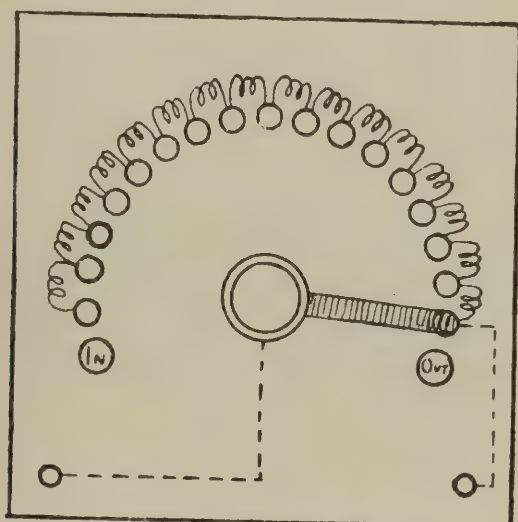


Fig. 84.—Field Regulator.

marked "out." The handle is of a much lighter nature than that of the starter, and does not require any spring to keep it in any position. Fig. 84 shows the connections of the field regulator.

The Rotary Converter.—The machine itself consists of a heavy framework, inside which the field magnets are disposed, as shown in Fig. 85. The machine is a four-pole machine, opposite magnets being of the same polarity.

The armature coils are wound at an angle of ninety degrees, and a simple method of understanding the action may be obtained as follows. In Fig. 85 the armature is shown with a certain polarity marked on each of four equal parts of its periphery. Then it may

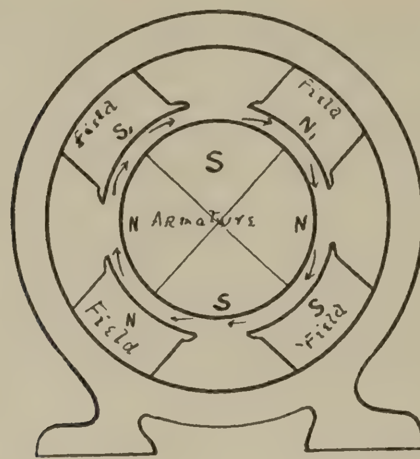


Fig. 85.—Action of Motor.

be said that while N_1 is attracting S, S_1 is repelling it, both forces tending to drive the armature in the direction shown by the arrows. A consideration of each separate set of poles will show that this force is continuously in the same direction.

Brush Adjustment.—The armature, as previously stated, is fitted with a commutator at one end and two slip rings at the other. The direct current is supplied to

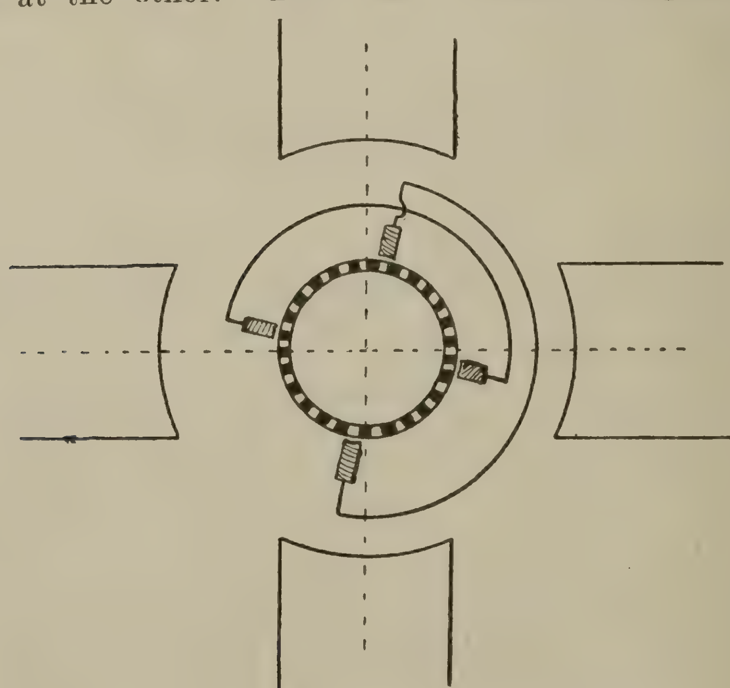
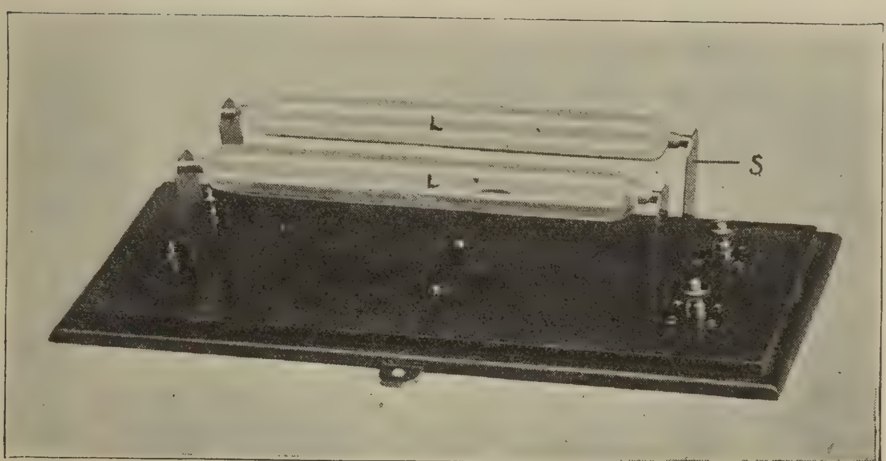


Fig. 86.—Connections and Disposition of D.C. Brushes.



GUARD LAMP BOARD

L, Straight filament lamps.—S, Brass springs.

the armature through four carbon brushes connected in pairs, as in Fig. 86. It is found that these brushes must rest in one particular position on the commutator, otherwise sparking between the brushes and the copper segments ensues, with the result that the commutator is so badly damaged in a short space of time that it has to be re-turned on a lathe. The exact position is found by experiment, and is usually a little distance in advance of the line joining the centres of two opposite field magnets, as in Fig. 86. This position is generally fixed by the makers, but provision is made for adjusting the brushes. The brushes are placed in brush-holders, which are fixed on pins attached to a movable portion of the framework of the machine. This portion is that through the centre of which passes the shaft of the armature, and it is so arranged that it is capable of rotation through a certain angle in the same direction as the armature.

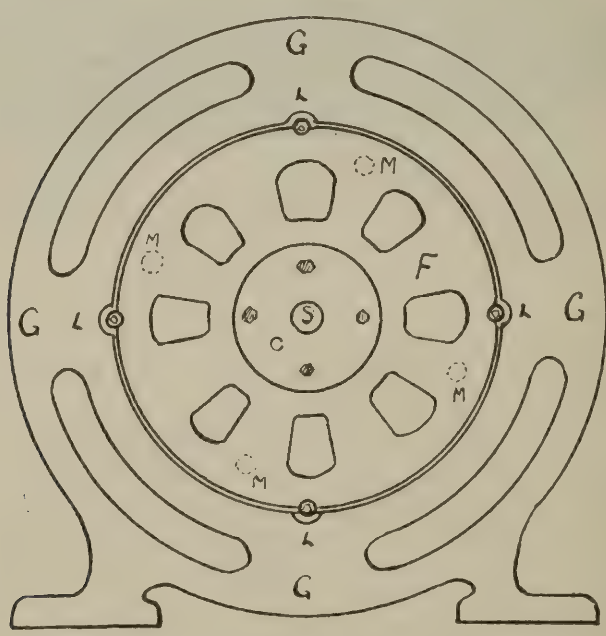


Fig. 87.—Diagram illustrating Brush Adjustment.

Fig. 87 represents a view of the machine at the commutator end. S is the end of the shaft, and C is a metal plate bolted to a similar plate on the other side of the part of the framework marked F. These two plates hold

the shaft bearings in position. F is a large circular plate, held in its place with respect to the main casting G by means of four bolts and washers, shown at the points marked L. This plate F carries four insulated standards, the approximate positions of which are shown by the dotted circles marked M. The brush-holders are clamped to these standards.

In order to alter the positions of the brushes all that is necessary is to slacken the bolts L and turn the plate F round until it lies in the required position, afterwards tightening up the bolts.

Brush-holder.—A diagram of the brush-holder is shown in Fig. 88.

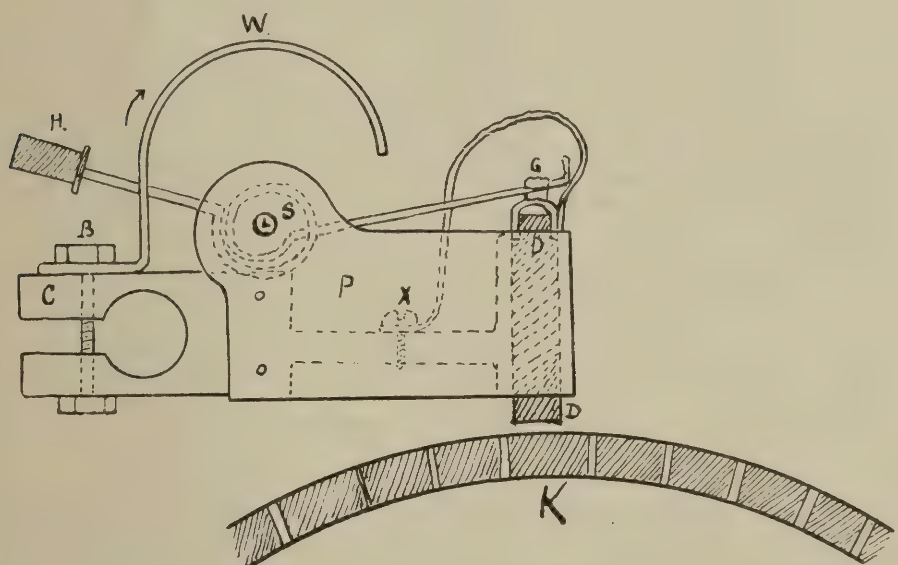


Fig. 88.—Brush Holder.

C is a brass cast clamp, through which the bolt B passes, and is used for clamping the holder to one of the standards previously mentioned. Two plates, P, are rivetted to this clamp, and at the point L between these plates a pin carrying the spring S is fixed. One end of this spring is supplied with a wooden handle, H, and the other end catches under a copper hook, G, which is permanently fixed to the carbon brush, D. The handle H may be moved in a direction shown by the arrow, and this movement puts tension on the spring S, thus causing the brush to make contact with the commutator K. The

part of the spring supplied with the handle moves through a toothed slot in the curved piece of brass shown at W, and by this means may be held in any particular position. The carbon brush D is kept in a rigid and upright position by means of a slot in the brass frame through which it moves, and is electrically connected to the holder by means of the flexible connection, shown partly in continuous and partly in dotted line, held in position by the screw X. The commutator is wider than the brushes, and consequently in order to ensure equal wearing of the whole surface the brushes are "staggered." Fig. 89 illustrates what is meant by this ex-

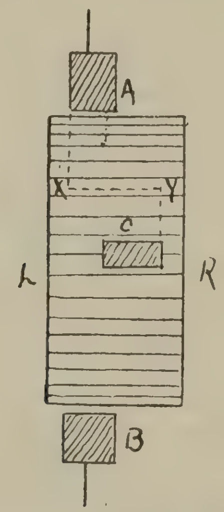


Fig. 89.—Position of Brushes on Commutator.

pression. A and B are diametrically opposite each other on the commutator, both being nearer the side marked L. The brush C is diametrically opposite another one, which cannot be shown in the drawing, but which we will call D. The brushes C and D are fixed nearer the side R of the commutator. Thus a part of the commutator which can be represented by the line xy is being evenly worn by the brushes.

Slip-rings.—Two brass rings are mounted on and carefully insulated from the shaft at the end, remote from the commutator. These rings are also insulated from each other by means of a fibre ring. Four carbon brushes are used in connection with these slip rings, being connected

in pairs in a similar manner to those used on the commutator. One pair of connected brushes is used in connection with each ring. This end of the shaft continues some way through the casing of the machine, and it is convenient to arrange a rocker to carry the brush-holders outside the casing. This rocker is shown in Fig 90.

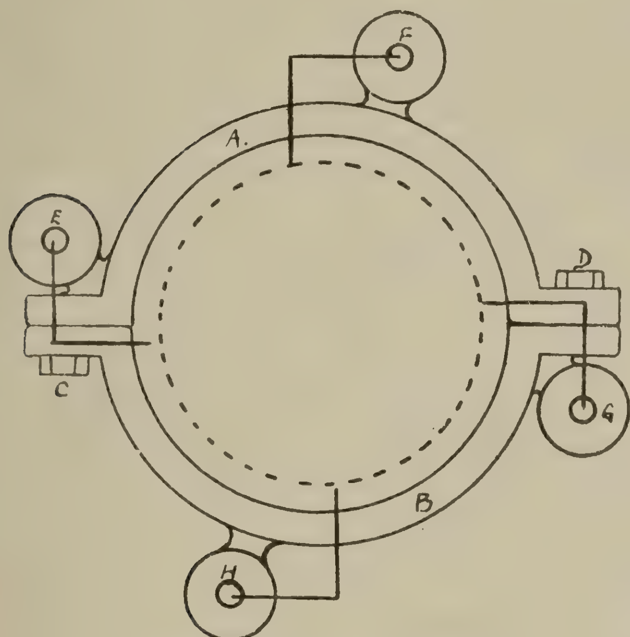


Fig. 90.—A.C. Brush Rocker.

It is cast in two halves, A and B, the two portions being clamped together round a part of the main casting by means of the screws C and D. At E, F, G, and H insulated standards are fixed to which the brush-holders may be clamped. If the dotted circle represents the slip rings the position of the brush-holders and brushes is approximately given by the straight lines terminating on the circle. It is usual to fix this rocker so that a line through the points L and M is horizontal. The position of these brushes with respect to the field magnets is immaterial, and if any sparking takes place it may be put down to dirty or uneven contact.

Connections.—The connections are shown in Fig. 92a, where it will be seen that one end of the field winding is connected to one of the D.C. brushes, the other end

being continued through an insulated hole in the casing of the machine marked "field." A connection from the brush which is connected to the field winding is brought through another insulated hole in the casing marked "line," while a connection from the remaining brush is brought through a third hole in the casing marked "armature."

Reading from left to right the holes through which the cable connections pass are marked respectively "armature," "field," and "line."

A connection is taken from the cable marked "line" to one pole of the main switch, and another from the cable marked "armature" to the terminal similarly marked on the starter. The cable marked "field" is connected to the terminal under the stud marked "out" on the field regulator—that is to say, the right-hand terminal.

A connection is taken from the "in" terminal of the field regulator to the terminal marked "field" on the starter, and finally a connection is made between the terminal marked "line" on the starter to the other side of the main switch.

A complete diagram of the direct current connections is given in Fig. 91. The connections marked A, B, and C are made with 7/16 I.R.V.B. (India-rubber vulcanised braided) lead sheathed cable, and the connections marked D, E are made with 3/22 I.R.V.B. lead sheathed cable.

The machine is built for a normal voltage of from 80 to 110 volts direct current, but is used on voltages as low as 60 and as high as 130 with satisfactory results. The normal speed is 1,500 revolutions per minute, and the variation obtainable by means of the field regulator is approximately 20 per cent. down and up.

Starting.—After seeing that the handle of the starter is in the "off" position, and that the field resistance is either all out or set for the required speed, the main switch may be closed and the handle H of the starter pulled over on to the first stud. The field magnets are now excited by the passage of the full current available, as there is no resistance in the field circuit.

The current through the armature windings has to pass through the total resistance in the starter, but since

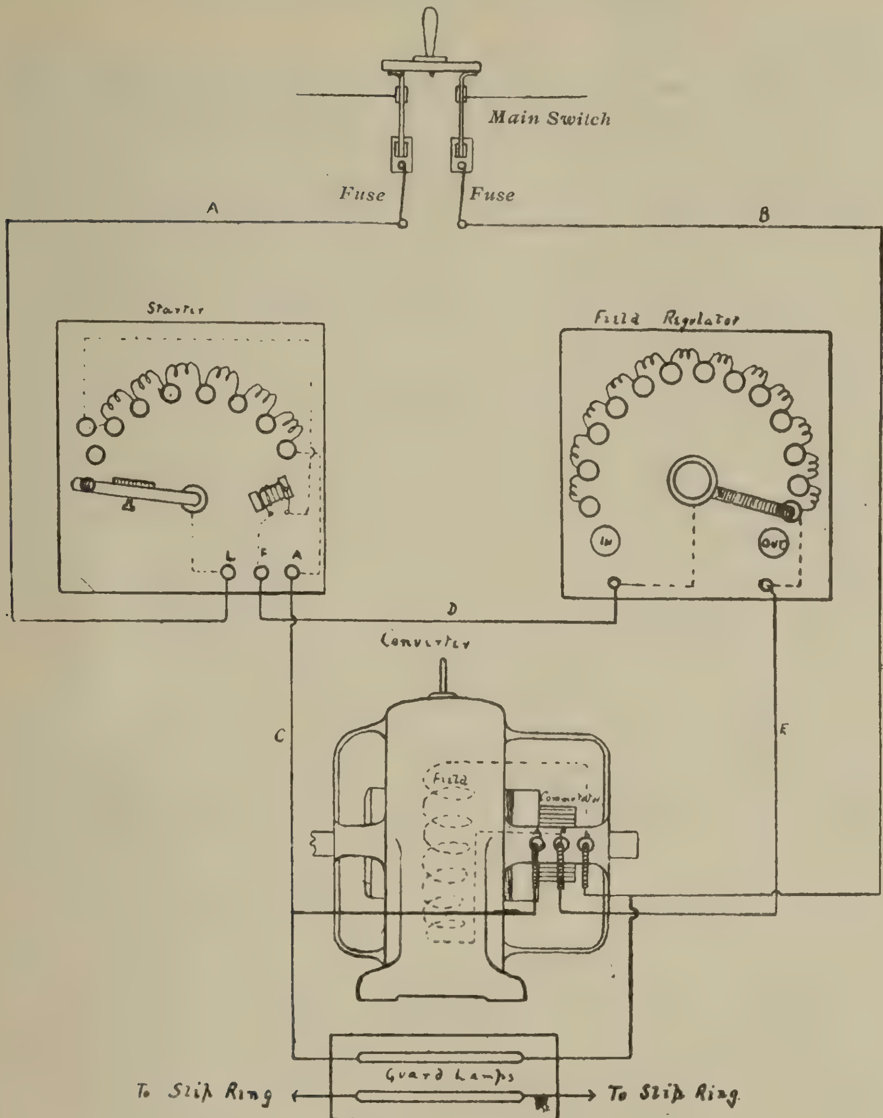


Fig. 91.—1½ K.W. Converter Connections.

the armature is not rotating there is no back E.M.F. to oppose that of the mains, so that a considerable current (about 1½ times the full working current) passes through the armature and starts it rotating. When the machine has acquired a constant speed with the handle on the first stop the handle may be carried forward on to the next one. This operation may be carried on, only passing from one stop to the next after the machine has come to a constant speed, until the handle comes to rest against the no-volt release, when it will be held there by the magnetism of the latter provided the tension of the

antagonistic spring in the handle is not too great. At this point the resistance, which is gradually put into the field circuit as it is taken out of the armature circuit, is once more cut out of circuit altogether, because, as previously stated, the magnet winding and the connection to the first stop are both connected to the metal bobbin of the no-volt release. The machine is now found to be running at a constant steady speed. If a greater

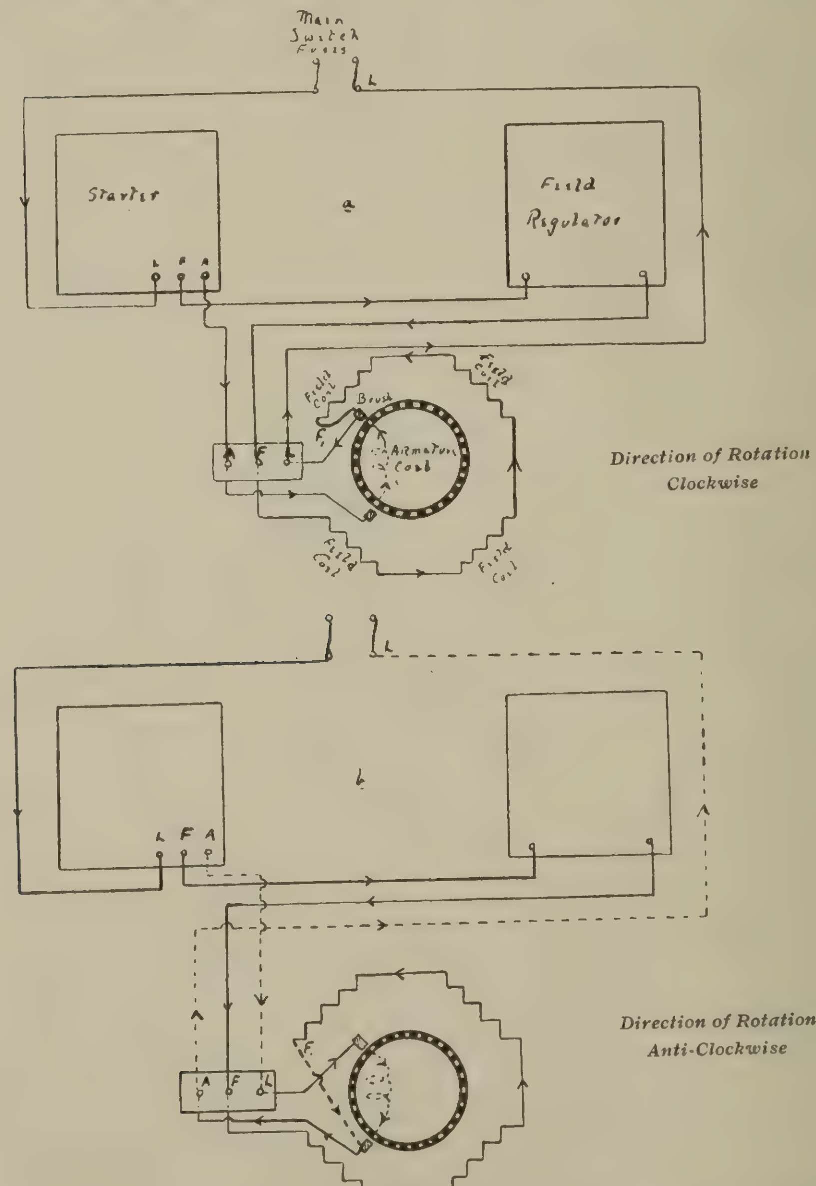


Fig. 92.—Wiring Diagrams for Changing Direction of Rotation of Armature.

speed be desired it is necessary to put in a little extra field resistance, or if a slower speed be required the removal of a little field resistance has the desired effect, these operations being effected by turning the handle of the field regulator either towards "in" or "out," as the case may be.

Direction of Rotation.—The direction of rotation of the armature may be changed by reversing the leads marked AA and LL in Fig. 92a so that they are arranged as in Fig. 92b, shown now as LA and AL. The connection between the end of the field winding marked F must also be removed from the top left-hand brush—looking at the machine from the commutator end—and be connected to the bottom left-hand brush. The necessary alterations are shown as dotted lines in the second figure.

Care of Machine.

Lubrication.—Brass cups are fitted over the bearings, which must be kept full of grease. Occasionally the cups must be taken off and as much of the old grease as it is possible to get at must be removed, the cup being refilled with clean grease. The cap of the cup must also be filled before replacing.

Commutator.—It is found that a certain amount of the carbon of the brushes is worn off and adheres to the surface of the commutator. If this be allowed to remain sparking will ensue to the detriment of the machine. This carbon is, however, very easily removed with a clean rag. If it cannot be removed in this manner a piece of very fine glasspaper may be used, and applied to the commutator whilst it is running by means of a wooden block so shaped as to fit on the surface of the commutator. On no account must emery cloth be used. It may be found advantageous occasionally to wipe the commutator with a cloth smeared with just a trace of clean vaseline, afterwards removing as much of the vaseline as possible with a clean cloth.

The machine must be kept as free as possible from oil and dust. The tension on the brushes must be only just sufficient to ensure good electrical contact with the commutator. In a great many cases the commutators have

been grooved and scored through carelessness on the part of operators in putting too much tension on the brushes. When the machine is revolving slowly there should be none of the shrieking sound which is so often met with. Any such noise is a clear indication that the brushes are pressing too tightly on the commutator.

Brushes.—The brush-holders should be so arranged as to leave about a quarter of an inch between the brasswork and the commutator. It will be found that after putting in a new brush a certain amount of sparking may take place. This will soon rectify itself as the surface of the brush adapts itself to the radius of the commutator. The upper end of the brush is fitted with a copper connection, and care must be taken that the brush is never so far worn that this copper comes in contact with the commutator, as this would result in great unevenness being produced.

The correct position for the brushes is that in which they are placed when a chisel mark on the disc carrying the brush-holders coincides with a second chisel mark on the frame of the machine.

Guard Lamps.—A straight filament lamp is usually connected in shunt across the armature leads, and another one across the field leads of the rotary converter, to protect the respective windings from any oscillatory surges which might be induced from the high frequency circuits during wireless transmission. The two lamps are mounted between two pairs of brass springs fixed on a base board supplied with terminals, as in Fig. 93.

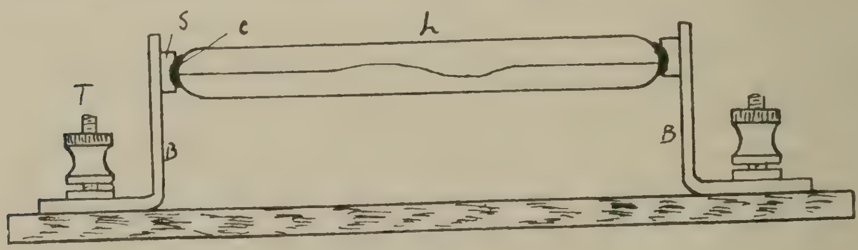


Fig. 93.—Guard Lamp Board.

Each of the springs marked B is fitted with a terminal, T, and a small socket, S, which takes the metal cap C at the end of the lamp L.

Low Frequency Primary Circuit.—The second circuit

1½ K.W. SHIP'S INSTALLATION AS FITTED IN LONDON SCHOOL.

A, Main switch.—B, Starter.—C, Field regulator.—D, Rotary converter.—E, Low frequency iron core inductance.—F, Magnetic key.—G, Manipulating keys.—H, Iolanda switchboard.—J, Transformer.—K, Air core choke coils.—L, Jigger primary.—M, Jigger secondary.—N, Discharger.—O, Transmitting condensers.—P, Aerial tuning inductance.—Q, High frequency sliding inductance.—R, Tuning lamp.—S, Earth arrester spark gaps.—T, Plain aerial plug sockets.—V, Marine type charging switchboard.—W, Magnetic detector.—X, Multiple Tuner.—Y, Ten inch induction coil.—Z, Telephone condenser.—Ac, Accumulator Battery.

to be discussed is the low frequency alternating circuit, which includes a switchboard, regulating inductance, manipulating key, magnetic key, and the primary winding of a transformer.

The Iolanda Switchboard.—This piece of apparatus consists of a slate panel mounted on a cast-iron frame and fitted with an ammeter, with shortcircuiting plug, a voltmeter, with key, a double pole switch, fuse ways, and a pilot lamp.

The switch is of the type already described in the D.C. circuit. The connections of the switchboard are

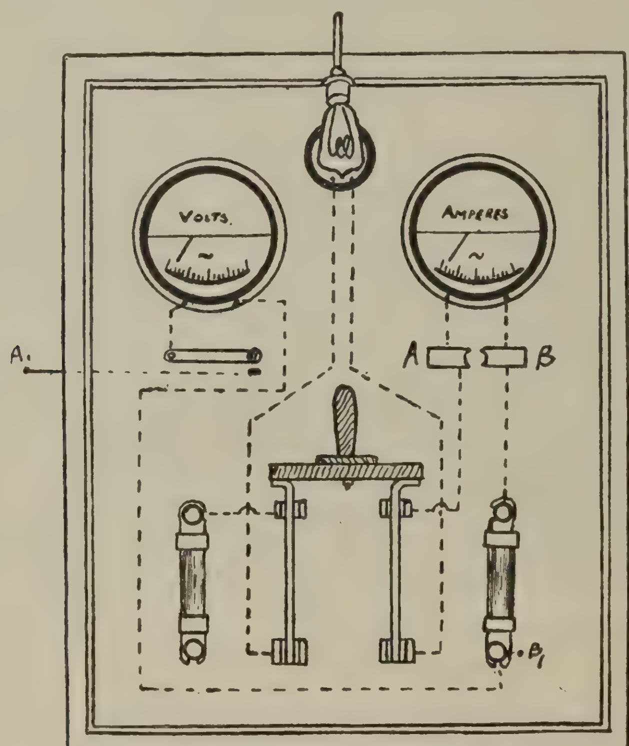


Fig. 94.—Iolanda Switchboard.

shown in Fig. 94. The feeding mains are brought from the brushes on the slip rings of the rotary-converter to the lower extremities of the switch.

Pilot Lamp.—These ends of the switch are also permanently connected to the pilot lamp, so that when the converter is supplying alternating current to the switchboard the lamp should glow whether the switch be closed or open. The sockets of the switch into which the upper

ends of the poles fit when the switch is closed are connected as follows. The left-hand socket to the upper end of a fuse directly and the right-hand socket to the upper end of another fuse, passing first through the ammeter.

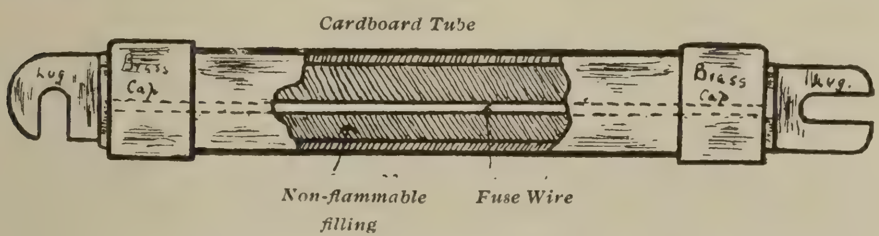


Fig. 95.—Cartridge Fuse.

Fuses.—These are of the cartridge type and capable of taking 30 ampères. The fuse wire is contained in a cardboard cylinder fitted with brass terminal lugs at either end, as in Fig. 95. The space between the wire

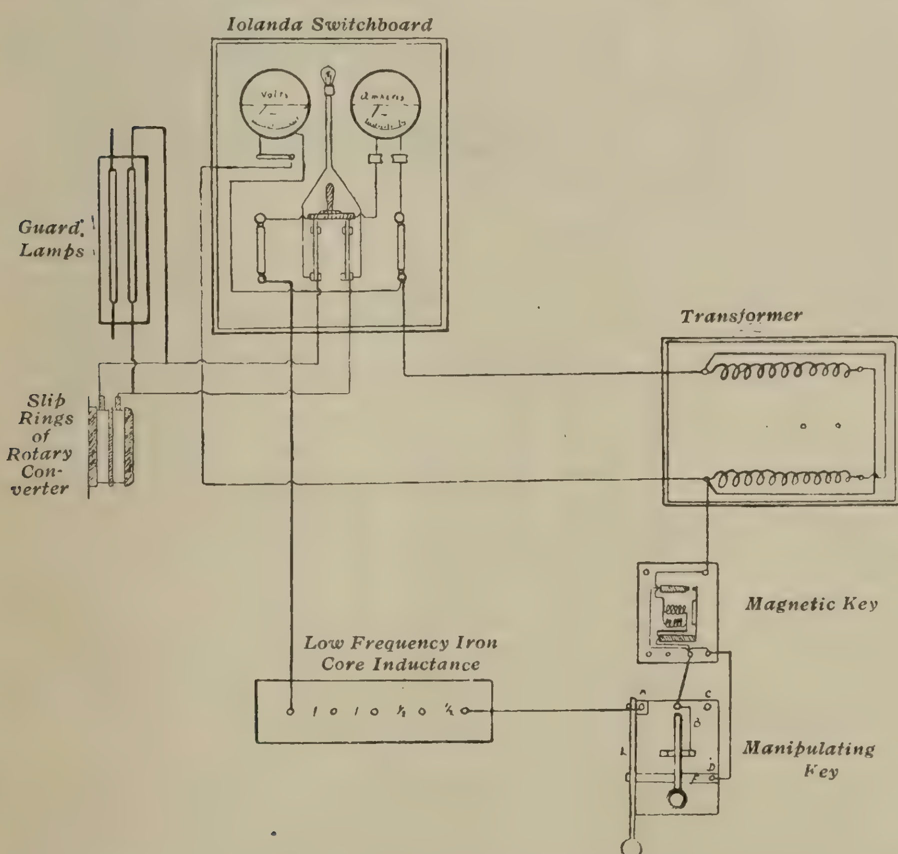


Fig. 96.—Low Frequency Primary Circuit.

and the case is filled with asbestos, sand, or other non-flammable material, and its use is, of course, to prevent the molten metal being scattered about in the event of the fuse blowing. The distributing leads to the remainder of this circuit are taken from the lower ends of the two fuses.

One side of the voltmeter is connected to the bottom of the right-hand fuse, and the other side is connected to the voltmeter key, the second terminal of which is supplied with a lug, from which a connection may be taken to one side of the transformer primary. Fig. 96 shows how the various pieces of apparatus used in this circuit are arranged in series, and each piece will now be discussed in proper order commencing at the left-hand fuse.

Low Frequency Iron Core Inductance.—This consists of two bobbins each wound with 360 turns of No. 12 D.C.C. (double cotton covered) copper wire wound in three layers. An open-ended iron wire core completely fills the interior of each bobbin. The two are mounted side by side in a teak box and connected in parallel, tappings being taken from suitable points to five terminals mounted along the centre of the box. The inductance obtainable has an approximate range of from ·001 to ·01 of a henry. The figures 1, 1, ½, ½, are stamped between the terminals, and refer to the amount of wire between

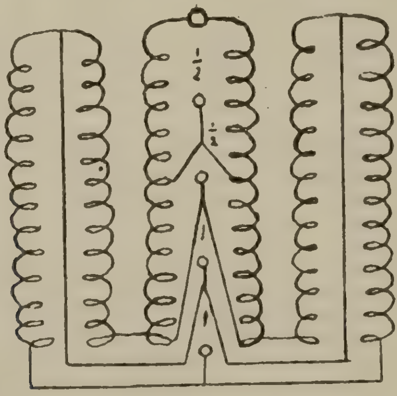
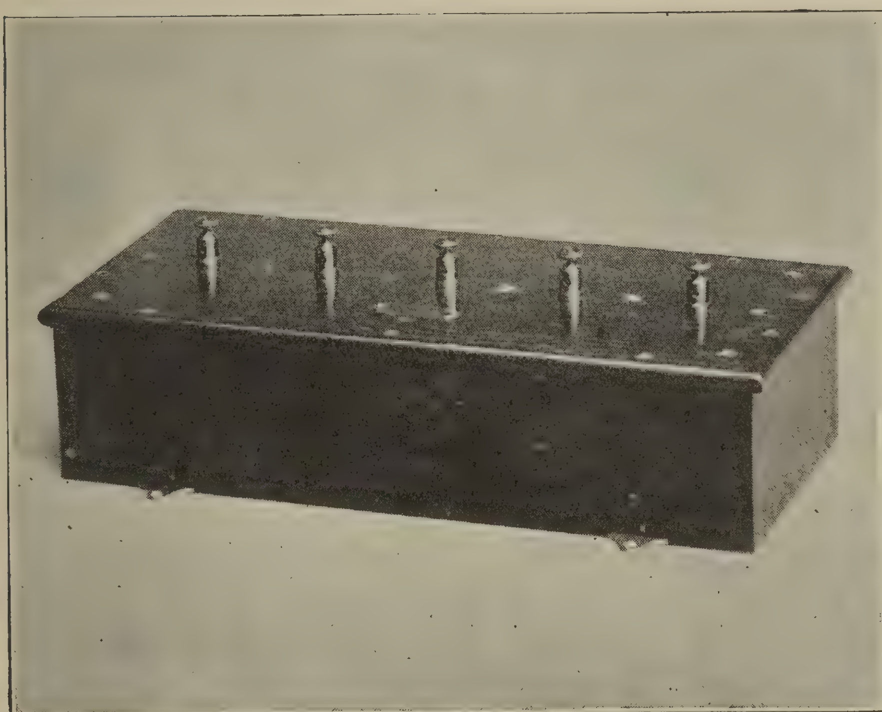


Fig. 97.—Low Frequency Iron Core Inductance.

the respective terminals reckoned in layers. Fig. 97 shows diagrammatically how the connections inside are



LOW FREQUENCY IRON CORE INDUCTANCE

arranged, each layer being represented for the sake of clearness as a separate coil.

The formula for the natural frequency of a circuit has already been given, and the phenomenon and effect of resonance briefly explained. If the leads from an alternating current machine be connected to the two sides of a condenser respectively we know that, in order to bring about resonance in the circuit, the capacity and inductance must be so adjusted that the frequency of the alternating current is the same as the natural frequency given by the formula

$$n=\frac{1}{2\pi\sqrt{CL}}$$

If the two leads be disconnected from the condenser and be connected to the ends of the primary winding of a transformer, the secondary being connected to the condenser, it is found that the formula for frequency must be modified to (see Figs. 98, a, b, c)—

$$n=\frac{1}{2\pi T\sqrt{CL}}$$

where T is the ratio between the number of turns of wire in the secondary to the number of turns in the primary.

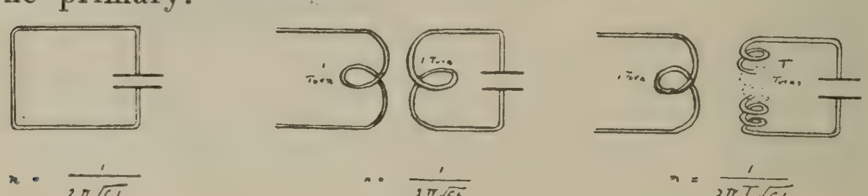
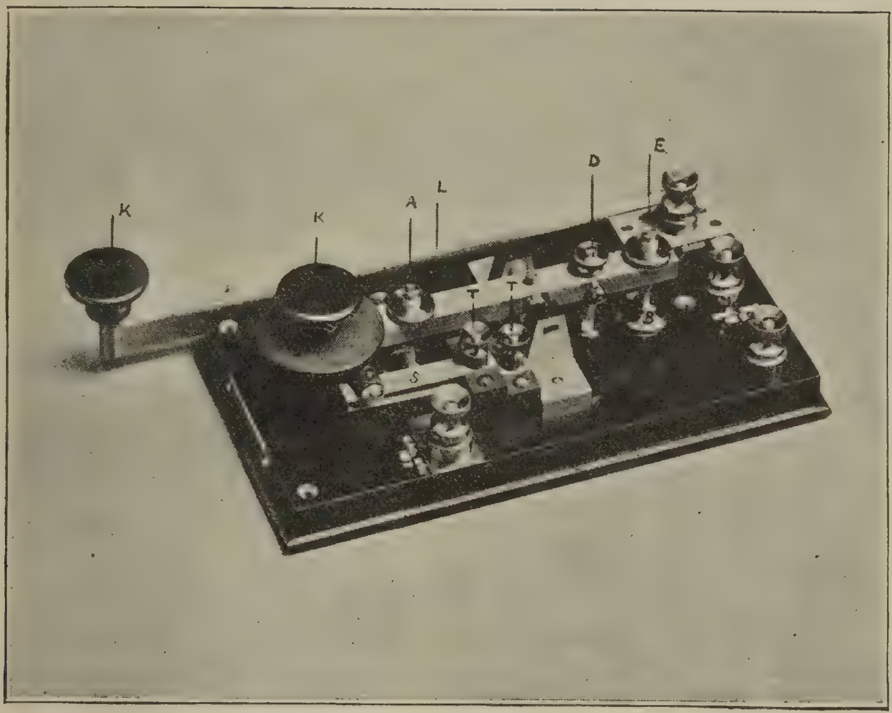


Fig. 98.—Natural Frequency of Circuit containing a Transformer.

Now the circuit under discussion is of this type, as will be seen later.

The use of this low frequency iron core inductance is therefore to put the circuit in resonance with the alternating current frequency, thus regulating the power at the disposal of the circuit for charging a condenser (to be discussed later).

The Manipulating Key.—This part of the circuit scarcely needs explanation. It is of a similar pattern to the ordinary telegraph key, with the exception that it is somewhat heavier. As heavy currents are to be



MANIPULATING KEY.

A, Contact adjusting screw.—B, Back stop.—C, Ebonite cam for adjusting short circuiting contacts.—D, Spring adjusting screw.—E, Back adjusting screw.—K, Ebonite knobs.—L, Side lever.—S, Telephone short circuiting springs.—T, Short circuiting terminals.

carried the platinum contact pieces are of rather large cross sectional area. The insulated knob is also of a heavier type, and the operator is further protected from a shock by means of an ebonite disc between the knob and the brass bar of the key.

The play of the key may be regulated by means of the adjustable back stop B, and the tension on the key by means of the spring S shown in Fig. 99. D is the

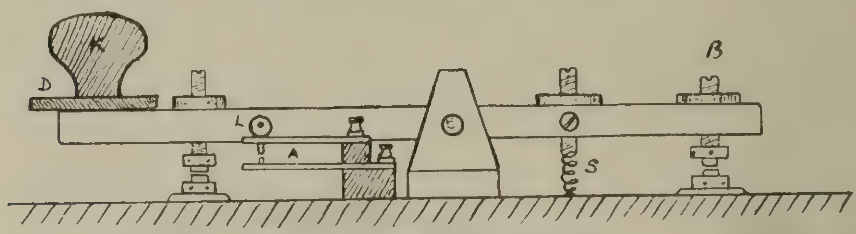
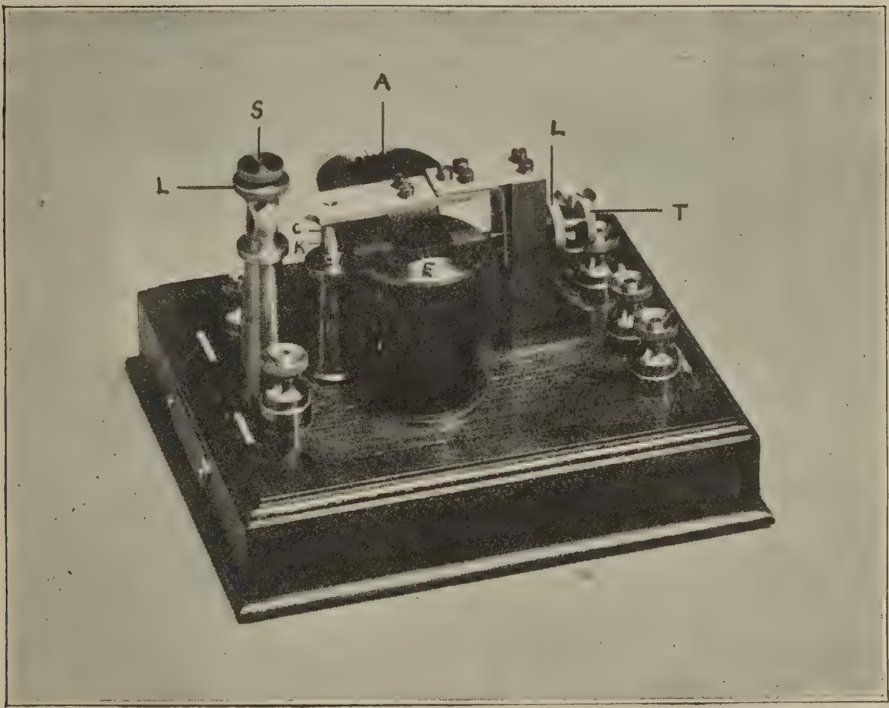


Fig. 99.—Manipulating Key.

ebonite disc and K the knob. A pair of small brass arms, A, fitted with contact pieces, the break between which is regulated by means of the cam L (consisting of a piece of ebonite tube with a hole eccentrically bored through it, and held in place by means of a brass pin screwed into the main bar of the key) is also supplied, the use of which will be explained later.

Fig. 96 shows a plan of the key. A side lever, L, with an ebonite handle, E, is used for breaking the circuit when desired. The internal connections between three terminals with which the key is fitted are also shown at A, B and C. A fourth terminal D is fitted on the end of a brass strip, F, running across the key, the other end of this strip forming a socket, in which the side lever rests. This key is used to form the dots and dashes of the Morse code by allowing the alternating current to flow only when it is depressed.

The Magnetic Key.—As already explained, the E.M.F. of an alternating current is continuously changing in direction and magnitude. If the circuit be broken at the manipulating key at a moment when this value is at a maximum a spark is formed at the contacts, which, in addition to burning away the expensive platinum, makes the contacts dirty and prevents rapid working. In order to obviate these two evils the magnetic key is



SINGLE MAGNETIC KEY.

A, Slotted armature.—C, Armature contact.—E, Electro-magnet bobbins.—K, Pillar contact.—L, Lock nut.—S, Adjusting screw for armature play.—T, Adjusting screw for tension of pring.

introduced. As its name implies, this key depends for its action on the principle of electro-magnetism. Two coils of No. 14 D.C.C. wire are wound on boxwood bobbins, which are mounted in parallel on two slotted soft iron cores fixed to an iron yoke in the base. A slotted armature is mounted above these coils on a brass arm, which is attached by means of a flexible spring at one end to a brass supporting pillar, and which carries on the under side of the other end a platinum contact. Immediately under this contact is a second one, which is fixed at the top of another supporting pillar. A third pillar carries a screw adjustment, by means of which the play between the two contacts may be adjusted. The connections between the various parts of this key are

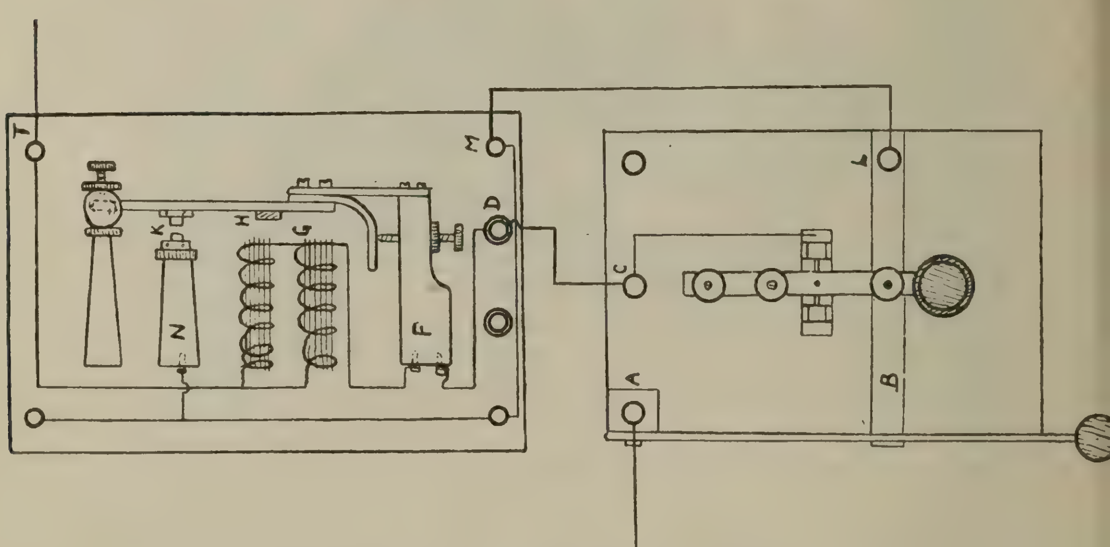
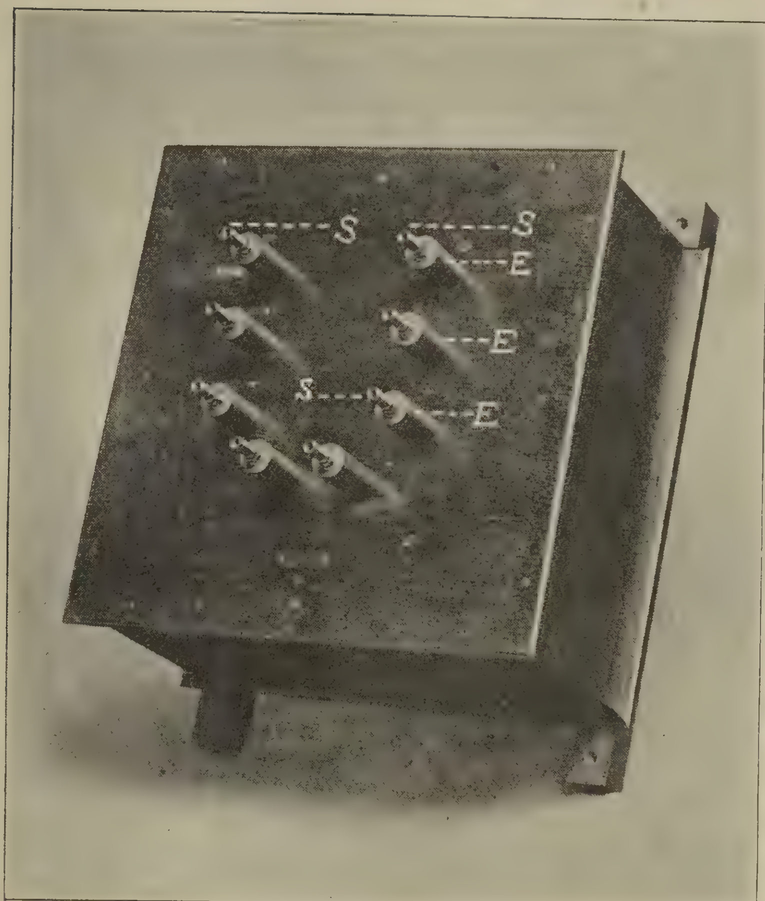


Fig. 100.—Magnetic Key Connections.

shown in Fig. 100. In order to better explain its action the manipulating key is also shown connected up.

Action of Magnetic Key.—Before depressing the manipulating key the circuit is broken. On depressing it, however, any current entering at A passes along the side lever to the brass strip B, through the front contacts and along the bar of the key to the terminal C, which is connected to the terminal D of the magnetic key. D is internally connected



AERIAL TUNING INDUCTANCE (TRANSMITTING).

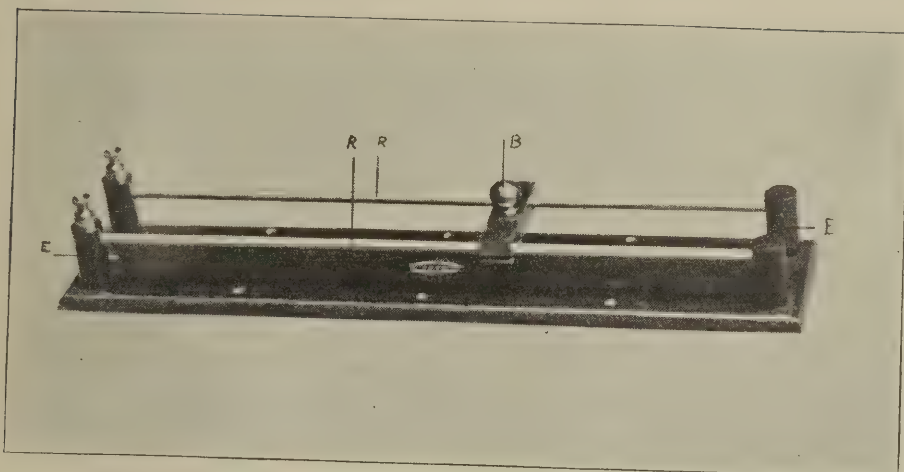
E, Ebonite bushes.—S, Brass plug sockets.

to the base of the pillar F, and also to the junction between the two coils at G. The other ends of the coils are connected to the terminal T. As the current passes through the coils the cores are powerfully magnetised and the armature H is attracted, contact being made at the point K. Returning to the manipulating key it is now seen that a second path has been provided for the current. It may pass completely along the brass strip B, and leaving the manipulating key at the terminal L enter the magnetic key at M, and after passing through the internal connection to the base of the pillar N it may continue up this pillar, through the contacts and along the armature, ultimately rejoining the original circuit at the base of the pillar F. Thus, if the manipulating key be released there is still a path along which the current may pass. But the current used in this circuit comes to a zero value 100 to 120 times per second, so that a point of zero value will follow immediately after the manipulating key has been released. When the current is zero its power to magnetise the cores of the coils is gone, and the armature flies back to its original position under the influence of the spring P, thus breaking the second circuit. As another path remains for the current to follow at the breaking of the manipulating key contacts, very little sparking occurs between them, and as the current is at zero value when this second path is broken very little sparking occurs at the magnetic key contacts, so that all chance of dirty or burnt contacts is obviated, and the operator is enabled to operate as fast as the hand can work.

The cores of the coils and the armature are slotted to prevent any residual magnetism remaining which would cause the armature to stick and not work at a great enough speed.

A simple theoretical diagram illustrating the working of the magnetic key is shown in Fig. 101.

Adjustment of Magnetic Key.—The following is a good method of adjusting the magnetic key. All tension should be removed from the antagonistic spring, and a piece of paper inserted between the magnet cores and the arma-



SLIDING INDUCTANCE.

B, Brass slider.—E, Ebonite pillars.—R, Brass rods.

ture. The pillar contact should then be screwed up until it is just touching the contact carried on the under side of the armature, and should be locked in this position by means of the lock-nut. Tension should then be put on the antagonistic spring until a space of about 1/16 of an inch separates the pillar and armature contacts.

The top stop may then be fixed so that it just touches the upper side of the bar carrying the armature.

The final adjustments must be made while the current is passing, and it will be found that delicate adjustments of the antagonistic spring and the top stop are required to eliminate successfully sparking between the contacts.

The Transformer.—This piece of apparatus consists of two transformer coils contained in a lead-lined teak box. Each coil consists of a primary winding of comparatively thick copper wire wound over a core of stranded soft iron wire, and a secondary of fine wire consisting of a great number of turns. The ends of the windings are brought through ebonite bushings to terminals on the lid of the container. These terminals are marked with positive and negative signs in such a way that it is practically impossible to connect up any of the windings in opposition. The primary terminals are arranged at the four corners of the lid, and the secondary terminals are arranged down the centre, as shown in Fig. 102. The position of the coils in the container is also shown. It will be seen that the primary and secondary windings may be arranged in series or parallel as desired. The primaries are almost invariably connected in parallel, but as both parallel and series arrangements of the secondaries are used diagrams are given showing the necessary connections (Figs. 102a and b). When the coils leave the works they are covered

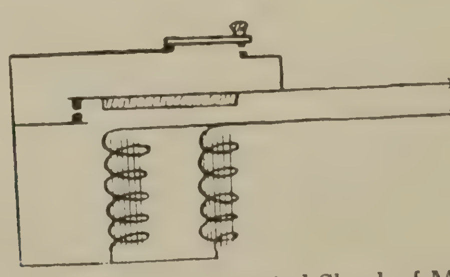
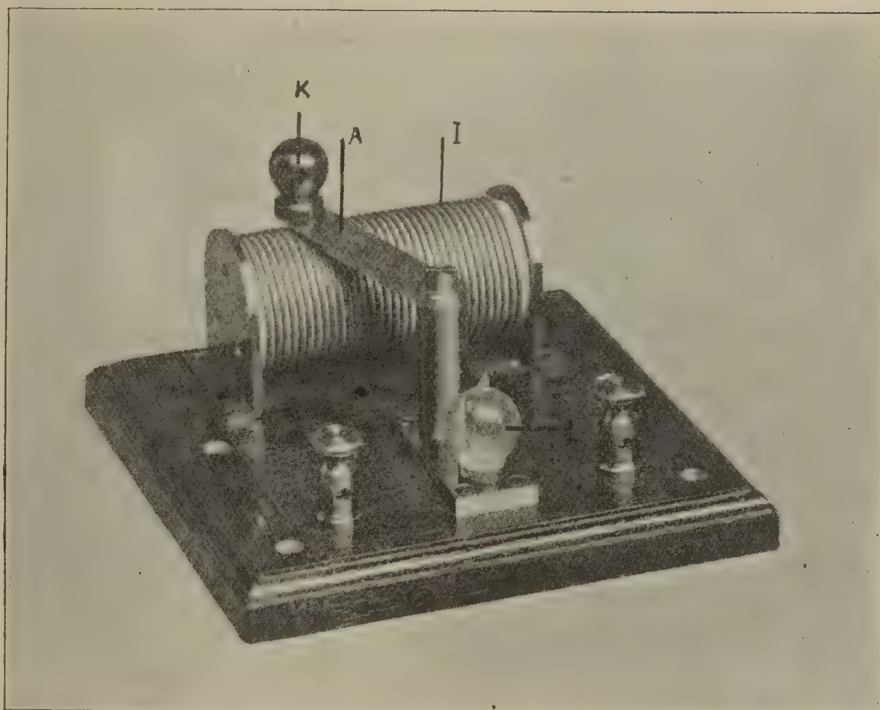


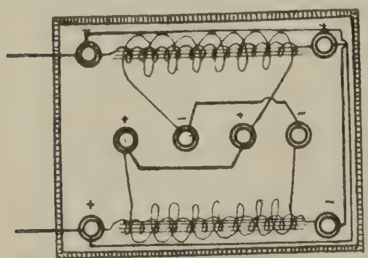
Fig. 101.—Theoretical Sketch of Magnetic Key.



TUNING LAMP.

A, Brass contact arm.—I, Copper inductance coil.—K, Ebonite knob.—L, 4-volt lamp.

with paraffin wax. On being placed in position the teak container is filled with high flash insulating oil, which eventually dissolves the wax and leaves the coils in a highly insulated condition.



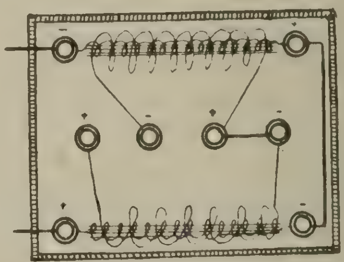


Fig. 102.—1½ K.W. Transformer Connections.

With the primaries in parallel and the secondaries in series the ratio between the primary voltage and the secondary voltage is approximately 1 : 300.

In Fig. 96 the voltmeter is shown connected across the primary winding of the transformer. The ammeter is, of course, in series with the circuit, and the readings of the two instruments give us an idea of the amount of power being used in the transformer primary. On a 110 volt D.C. circuit the readings should be about—

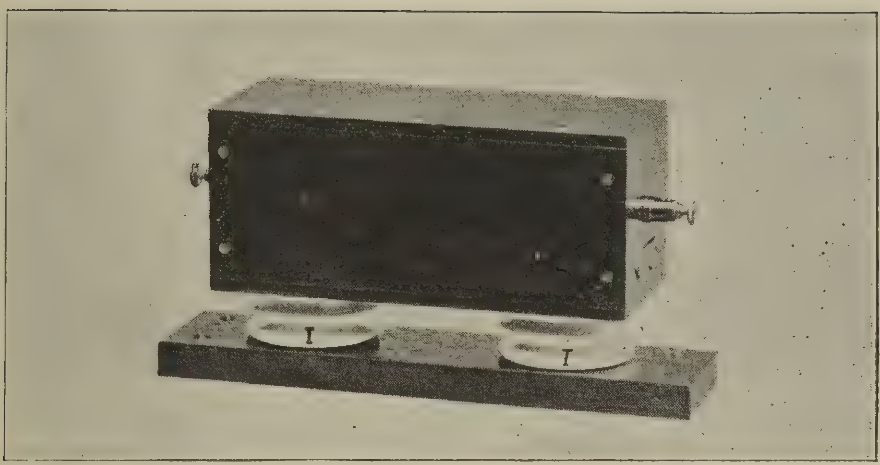
Ammeter ... ... 25 amps.
Voltmeter ... ... 75 volts.

(See paragraph on Tuning of Low Frequency Primary Circuit, page 233.)

It has been stated that the power is obtained by multiplying the volts by the ampères, and in this case the result is 1·875 K.W. It must be remembered, however, that we are dealing with alternating current, and that the potential is not at a maximum value at the same time that the current is at a maximum value. The difference of time between the two maximum values is reckoned in degrees in terms of what is known as the angle of lag, and for calculating the power of an alternating current the equation becomes

Power in watts = Virtual ampères × Virtual volts
× Cosine of angle of lag.

The cosine of the angle being always less than unity, the total number of watts is always less than



AIR CORE CHOKE COIL.

I, Porcelain insulators.

the result obtained by simply multiplying the ampères by the volts taken from the instrument readings. At first sight operators are apt to ask why they can get 1·875K.W. out of a 1·5K.W. set, and the above, of course, explains where the mistake is made.

HIGH TENSION CIRCUIT.—The next circuit to be considered is called the high tension or high voltage circuit, the main parts of which are the transformer secondary windings, two air-core choke coils, and the main condenser. The first require very little explanation, as the connections have already been given under the heading of "Transformer" in the explanation of the last-mentioned circuit.

The Choke Coils (Air Cores).—These consist of a coil of fine wire on an insulated stand contained in a teak box. They have a resistance of about 15 ohms. The total impedance in a circuit containing inductance and capacity is given from the formula

$$\text{Impedance equals } \sqrt{R^2 + \left(2\pi nL - \frac{1}{2\pi nK}\right)^2}$$

where R represents resistance, n the frequency, L the inductance, and K the capacity. From this it is seen that if n be increased the impedance increases.

In the case of the coils under discussion the value of n in the case of the alternating current is so low that the current has no difficulty in passing through them. In the next circuit to be considered, oscillating currents in which n has an exceedingly high value are circulating; and as the main condenser is common to the two circuits, these chokes prevent the oscillating currents from passing back to the transformer windings, because the value of the impedance for the extremely large value of n is too great to permit of such a flow of current.

Again, the value of R is very much greater for a high frequency current than for a direct or low frequency current. It is found that currents of high frequency are confined to the surface of a conductor, and do not distribute themselves uniformly through it.

The heating effect in a conductor is proportional to the square of the current, and if the current is unevenly

distributed the heat produced, and hence the resistance of the conductor, becomes much greater.

It will be seen, therefore, that the value of R in the calculation for impedance also tends to increase the total value of the latter for high frequency oscillations and makes the choking effect more pronounced.

It may be mentioned further that the conductors in the oscillatory circuits are invariably made of large surface, consisting either of copper strip, copper tube, or cable containing a great number of strands in order to make the skin resistance as low as possible.

The Main Condenser.—This piece of apparatus is used to store up the energy for the production of oscillating currents in a closed oscillatory circuit.

As this condenser has to withstand very high voltages the dielectric consists of the best flint glass. The condenser consists of a lead-lined teak container, in which two separate banks of sheet zinc and glass are placed; each bank being carried in a zinc cradle to facilitate its removal for purposes of repair or adjustment. In each bank there are 35 sheets of zinc shaped as in Fig. 103 and 36 sheets of glass. The zincs are alternately

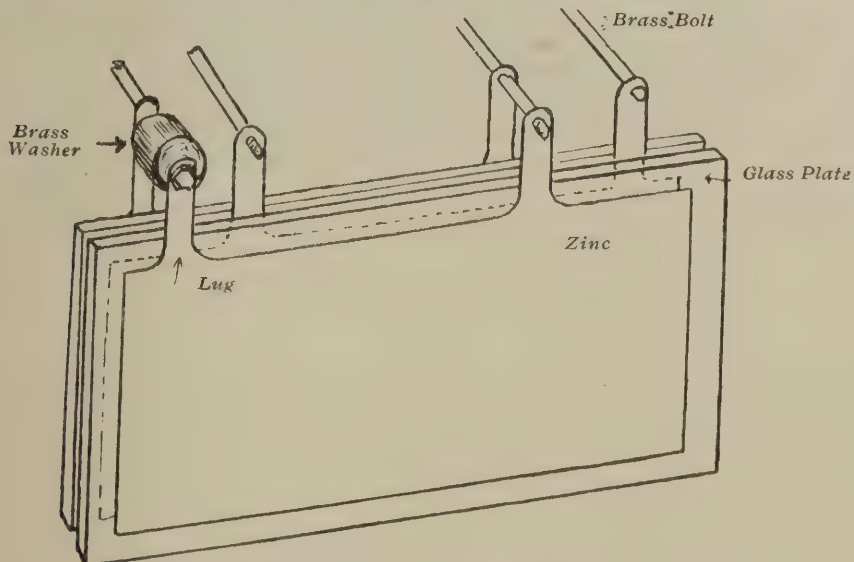
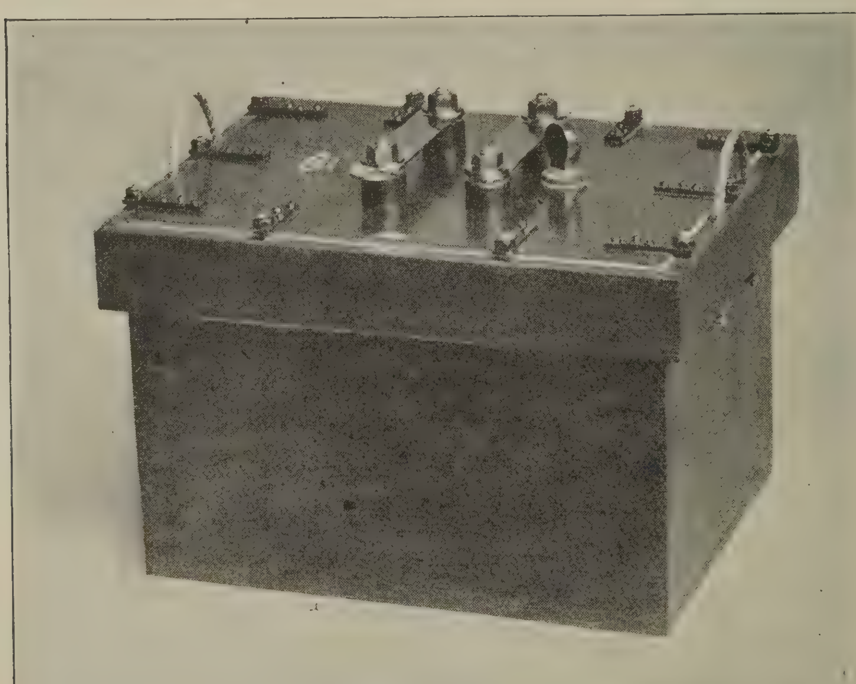


Fig. 103.—Arrangement of Plates in Main Condenser.

arranged with the lugs as shown, a sheet of glass being placed between every two adjacent zincs. It is thus seen that 17 zincs have one lug near the right-hand edge of

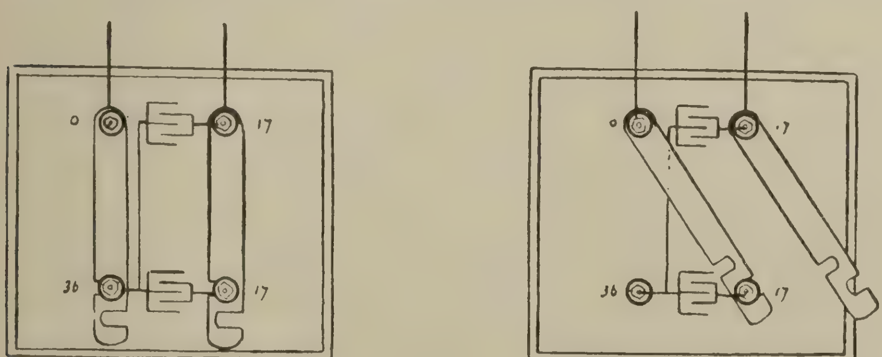


HALF PLATE CONDENSER (CLOSED)

the glass plates and 18 zincs have one lug near the left-hand edge of the glass. The 17 plates are connected by means of brass bolts supplied with washers to keep the lugs in a rigid upright position. The height of the brass bolts above the top edge of the glass plates is fixed by means of small leather stools. The 18 plates are similarly connected together. Only 34 of the 36 glass plates are active, the remaining two being guard plates. Each set of zincs has two brass bolts, one through each set of lugs, thus ensuring a perfectly rigid disposition between the glass plates. Each bank is similarly built up and stands in its cradle on a cork pad, being packed on the sides with white wood. Small U-shaped copper strips are used to connect the bolts of the two sets of 18 zincs, the two cradles being so placed in the container that the 18 zincs of each are in line.

The lid of the container is fitted with four brass terminals, each passing through heavy ebonite bushing. One of these terminals is marked with a cypher and has no internal connection. Two terminals marked "seventeen" are each connected to the middle of one of the bolts connecting each set of seventeen zincs. The fourth terminal marked 36 is connected to the middle of one of the bolts connecting one set of 18 plates.

The two parts of the condenser may be very quickly placed either in parallel or series by means of two brass connecting strips, each being drilled at one end and slotted at the other. When the two strips are parallel to each other, as in Fig. 104a, the two halves of the condenser are in parallel, as is seen from the conventional



Parallel.
A

Series.
B

Fig. 104.—Main Condenser Connections.

drawing of the condensers. When they are in a diagonal position, as in Fig. 104b, the two halves are connected in series. Since each half is exactly similar to the other, the capacity of the parallel arrangement is four times that of the series arrangement, because for parallel capacities

$$K=C+C=2C$$

and for series capacities

$$\frac{1}{K}=\frac{1}{C}+\frac{1}{C}=\frac{2}{C} \text{ or } K=\frac{C}{2}$$

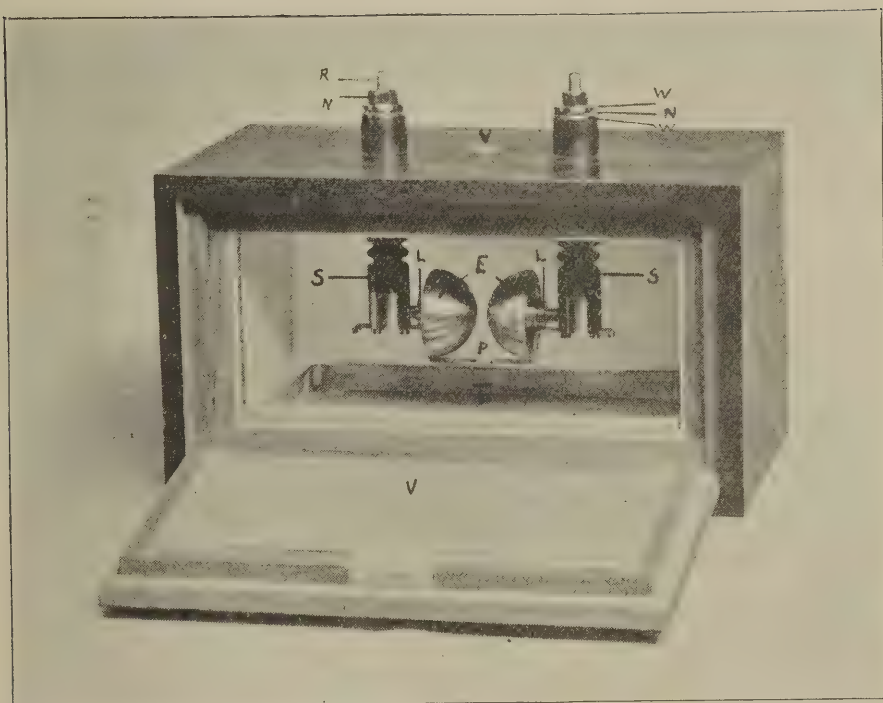
The capacity of each half is about ·0325 microfarads, so that the capacity of the series arrangement is ·01625 microfarads and that of the parallel arrangement is ·065 microfarads.

The glass plates are $\frac{1}{10}$th of an inch thick, and each plate is separately tested to stand a voltage of at least 27,000 volts. The main terminals are the ones marked 0 and 17 on the same bank.

If the condenser in a closed oscillating circuit consists, say, of a Leyden jar, it is often found that a brush discharge takes place between the edges of the inner and outer coatings of foil. The brush discharge consists of a great number of fine twig-like ramifications, which are seen to start from the foil edges and spread out towards the edge of the dielectric. These discharges are accompanied by a sharp hissing or crackling sound, and, of course, a great deal of the energy of the condenser is lost. To reduce the loss as much as possible the glass is usually coated with some non-hygroscopic insulating material, such as shellac varnish.

In the case of the main condenser just described, brush discharging is prevented by immersing the condenser banks in high flash insulating oil.

The High Frequency Primary or Closed Oscillating Circuit.—The main condenser forms part of this circuit and is connected in series with a discharger, a variable inductance, and the primary of an oscillation transformer, which last is more usually called a jigger, as it is used for the transformation of trains of oscillations or "jigs," as they have been styled, from one circuit to another. One side of the main condenser is connected to one terminal of the discharger.



DISCHARGER (FIXED TYPE).

E, Cast iron electrodes.—L, Lock nuts.—N, Lock nuts.—P, Protective spark points.—R, Brass rod.—S, Ebonite pillars.—T, Zinc tray.—V, Chamois leather covered vent holes.—W, Brass washers.

The Discharger.—The spark discharges across two mushroom-shaped cast-iron electrodes, which are mounted on two horizontal brass spindles supported on vertical brass rods. These brass rods pass through heavy ebonite pillars, which are brought to the outside of a teak container, and are supplied on their upper extremities with suitable washers and nuts for making the required external connections. The container is made of 1½ inch teak, and is lined first with asbestos and afterwards with lead in order to deaden the sound of the discharge. A zinc tray is placed in the bottom of the container, in which quicklime is placed to absorb the moisture and gases produced when the spark is taking place. The cast iron electrodes are screwed on to the horizontal spindles, the thread on which is of such a pitch that one half turn gives an adjustment of one millimetre. Lock nuts are provided so that when the electrodes have been set to a proper distance apart they can be permanently fixed in position. Two sliding brass strips are mounted immediately under the electrodes and are set at such a distance apart that all danger of the condenser breaking down through excessive voltage is avoided. Fig. 105 shows this

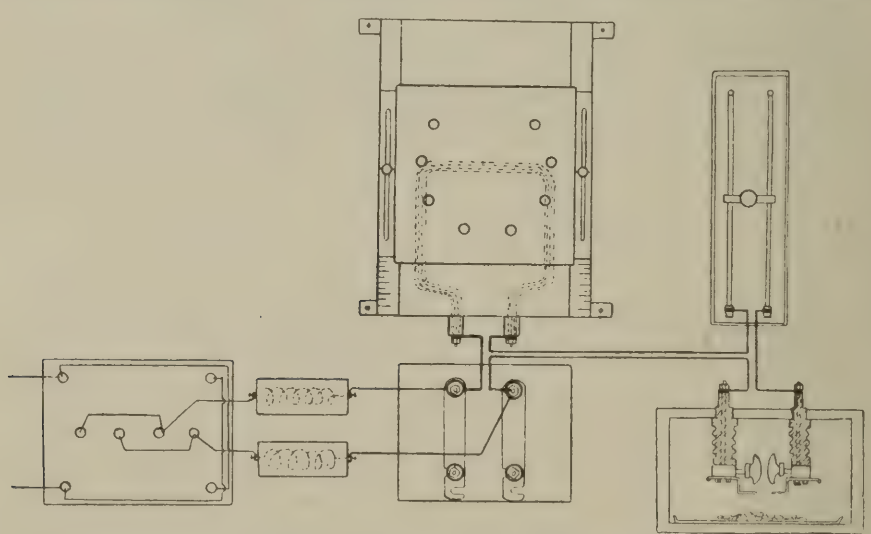


Fig. 105.—High Tension and Closed Oscillating Circuits.

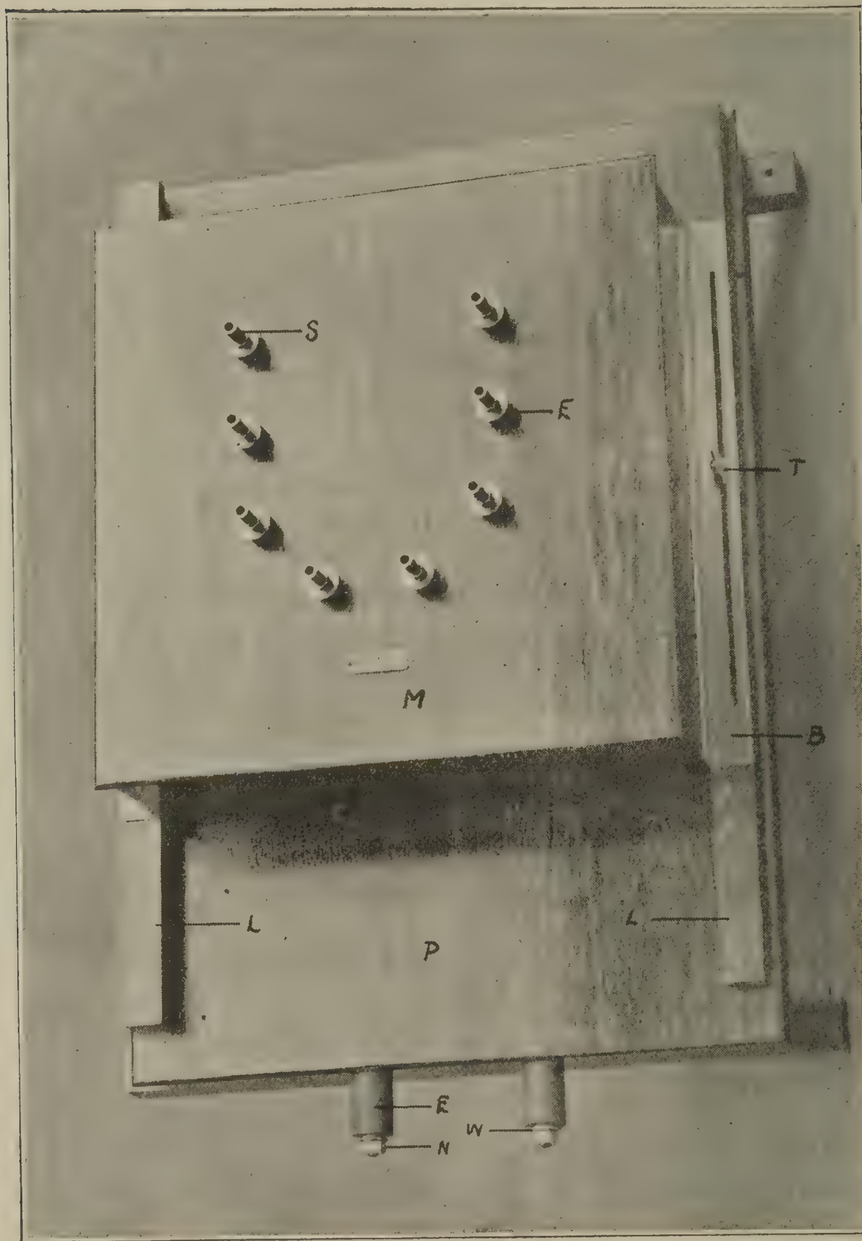
discharger and does not require any further explanation. The second terminal of the discharger is connected to one side of the high-frequency sliding inductance.

The High-frequency Sliding Inductance.—This consists of two brass rods of round sectional area mounted on four ebonite pillars on a wooden base, bridged by a sliding brass clamp by means of which the inductance may be varied. The minimum inductance is zero as the two rods are shorted, and the maximum is about 26 microhenries. The condenser, it will be remembered, is only capable of adjustment for two capacities, or, admitting the possibility of using one bank separately, for three. This sliding inductance is therefore necessary for obtaining a final slight adjustment for the production of oscillations of the required frequency. This instrument is shown in Fig. 105.

The Jigger.—This instrument consists of a primary winding of one turn and a secondary of eight turns. The primary winding is built up of 63 strands of No. 20 copper wire, each strand being cotton-insulated and the whole impregnated with paraffin wax and shellaced. It is wound round a wooden former, square in shape, and the two ends are brought through heavy ebonite bushes through the bottom of the teak box in which it is contained and are soldered into terminal sockets. One end is connected to the second end of the high-frequency sliding inductance and the other end is connected to the main condenser, thus completing the closed oscillating circuit. Two standard wave lengths are used on board ship—namely, 300 and 600 metres, or approximately 1,000 and 2,000 feet. The adjustment of the closed oscillating circuit for the production of the longer wave is shown in Fig. 105. The banks of the main condenser are placed in parallel and the spark-gap is adjusted to approximately 4 millimetres. The bridge of the sliding inductance is placed in a certain position indicated on a drawing which is left on the station by the erecting engineer. The secondary windings of the transformer are connected in parallel.

SHORT WAVE ADJUSTMENTS.

For the production of the shorter wave the main condenser banks are connected in series, the spark gap is increased to approximately 8 millimetres, the sliding inductance is altered in accordance with the engineer's



TRANSMITTING JIGGER (NORTH FORELAND TYPE).

B. Brass slider.—E. Ebonite bush.—L. Coupling calibration.—M. Jigger secondary casing.—N. Terminal nuts.—P. Jigger primary casing.—S. Brass plug sockets.—T. Brass thumb screws.—W. Brass washers.

diagram, and the secondary windings of the transformer are connected in series. The reason for this last change is as follows.

The energy of a charged condenser is obtained from the formula—

$$E=\frac{CV^2}{2}$$

where E is the energy, C the capacity, and V the voltage to which the condenser is charged.

Let us consider this equation in connection with the two arrangements for the short wave and long wave respectively.

Let E and E_1 represent the respective energies
" C " C_1 " " " capacities
" V " V_1 " " " voltages

$$\text{Then } E=\frac{CV^2}{2}$$

$$\text{and } E_1=\frac{C_1V_1^2}{2}$$

In order, then, that the energy in the condenser may be the same in each case

$$E=E_1 \text{ or } \frac{CV^2}{2}=\frac{C_1V_1^2}{2}$$

It has already been shown that $C_1=4C$
Substituting in the above equation, therefore,

$$\frac{CV^2}{2}=\frac{4CV_1^2}{2}$$

multiplying each side by $\frac{2}{C}$ we get

$$V^2=4V_1^2$$

and taking the square root of each side

$$V=2V_1$$

Hence we see that the voltage for the short wave arrangement must be twice that for the long wave arrangement in order to obtain the same energy. This increase in voltage is obtained by placing the secondary windings of the transformer in series instead of parallel. In consequence of the increased voltage the spark gap must be increased in order to avoid arcing.

The connections between the various pieces of apparatus in the closed oscillating circuit are made by means

of standardised pieces of copper strip, and in order to keep the inductance as low as possible these strips are placed very close together, any sparking between them being prevented by means of ebonite sheets held in position by ebonite buttons. The disposition of the connections, ebonite separators and buttons is shown in Fig. 106.

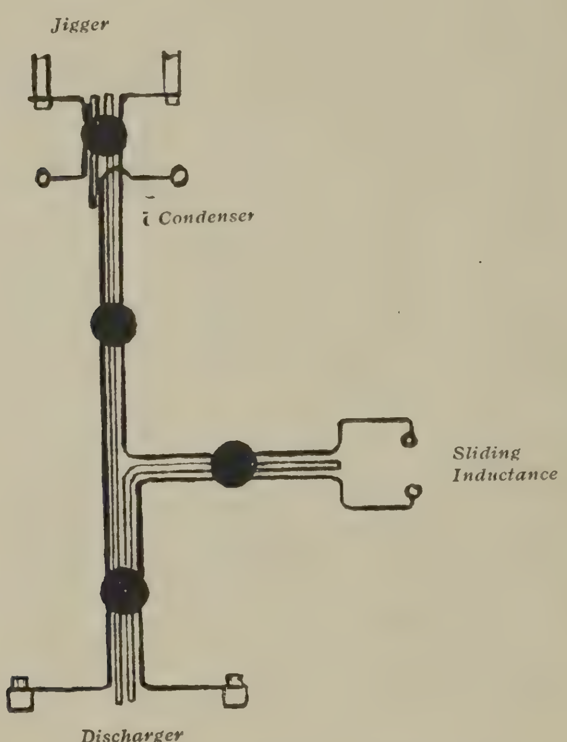


Fig. 106.—Closed Oscillating Circuit Connections with Separators.

The Radiating or Open Oscillating Circuit.—This is the last circuit in connection with the transmitting apparatus. It consists of the secondary winding of the jigger, an aerial tuning inductance, an earth-arrester spark gap and a tuning lamp.

The jigger secondary is a coil of eight turns of cable made up of 21 strands of No. 20 copper wire, each strand cotton-covered. A coil of rope is wound between the turns of this winding, the whole arrangement being wound round a square wooden former and afterwards shellaced. Tappings to eight brass sockets placed on the face of the

box in which the secondary is contained are taken through ebonite insulating bushes. For practical purposes there are seven turns, each one being a trifle more than one actual turn in order that the tappings may be suitably disposed round the face of the container. The right-hand socket is connected to the turn nearest the primary winding and is marked earth; the inductance of the winding, commencing from this earth terminal and adding one turn at a time, is 1·4, 4, 7·5, 10·8, 16·4, 21 and 25·8 microhenries. The box containing the secondary is made to slide over the box containing the primary, thus permitting of a variation of the coupling. A scale on the primary box indicates to a certain extent the percentage of coupling, but does not, of course, give a definite reading, as the coupling depends to a certain extent on the aerial used, the inductance of the radiating circuit being distributed throughout its length.

The Aerial Tuning Inductance.—Twenty turns of cable made of 19 strands of No. 20 wire, the whole being vulcanised and braided, are wound round a square wooden former. Tappings are brought from various points to eight brass sockets arranged on the face of the teak containing-box through ebonite insulating bushes, the number of turns between the various sockets being shown in Fig. 107. It is seen that it is possible to obtain any

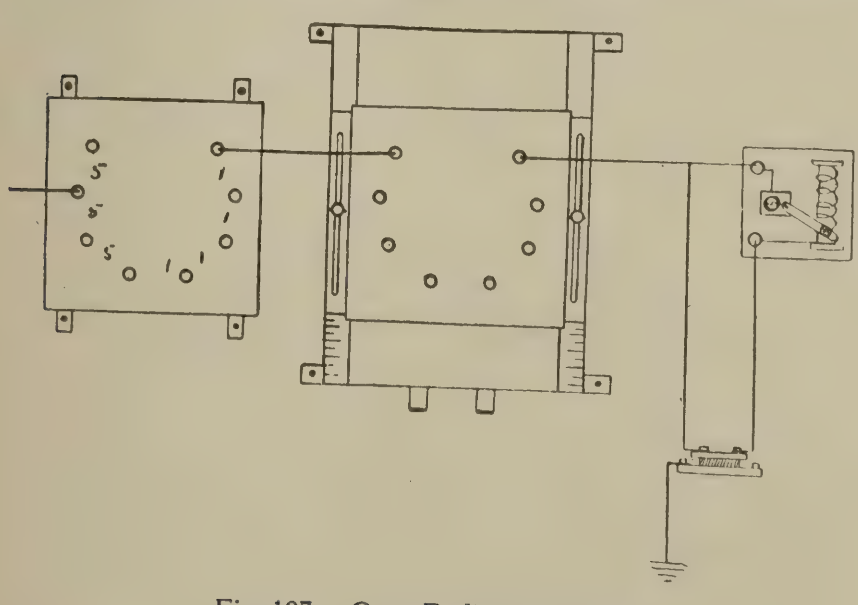


Fig. 107.—Open Radiating Circuit.

number of turns from one to nineteen by taking suitable connections from the sockets. The inductance measured from the right-hand terminal, and taking one additional section at a time, is 1, 3·25, 8·5, 17, 52, 94·4, and 150·6 microhenries. As in the case of the jigger secondary, there is really one more turn than is accounted for by the numbers marked on the face of the box, this being to provide that all the tappings occur at a fraction over the complete turn, so that they do not come directly under each other. As there is no variable condenser in the open oscillating circuit the oscillating constant can only be varied by altering the inductance, and this piece of apparatus is designed for such an operation. A long aerial has a larger capacity and inductance than a short one, so that less of this aerial tuning inductance is required in connection with a long than with a short aerial for the production of the same wave length.

The Earth Arrester Spark Gap.—This consists of two brass circular plates separated at a distance of one-hundredth of an inch from each other by means of a mica disc, each plate being supplied with four terminal nuts. The upper plate is kept in a rigid position with respect to the lower one by means of a brass pin fixed in the centre of the latter, which passes through an ebonite bushed hole in the centre of the former, a lock nut being screwed on to the upper extremity of the pin. A circular groove is made in each plate coinciding with the edge of the mica disc to prevent sparking and burning at the edge of the mica. A section through a diameter of the arrester is shown in Fig. 108.

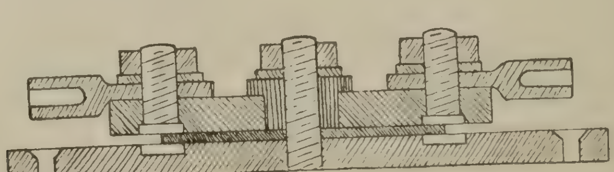


Fig. 108.—Earth Arrester Spark Gap, Mica Disc Type.

The Tuning Lamp.—This consists of a four-volt lamp in series with an adjustable inductance coil mounted on a teak base. The inductance coil is wound with 8 ft. bare No. 16 copper wire on a grooved boxwood core. One end of the winding is free and the other end is con-

EARTH ARRESTER (MICA DISC TYPE).

B. Bottom Plate.—E. Ebonite bush.—L. Brass lug.—N. Brass nut.—
T. Top plate.—W. Brass washer.

nected to a terminal on the baseboard. A second terminal is connected to one of the lamp contacts, the other contact being connected to a pivoted brass arm, the extreme end of which may be moved over the copper wire inductance. The connections are shown in Fig. 107.

The connections of the various parts of this circuit are shown in Fig. 107. The lower end of the aerial is connected by means of a flexible lead of seventy strands of No. 40 copper wire, to one end of which is attached a wood-handled brass plug, to the required socket of the aerial tuning inductance. A second flexible connection, with a similar plug at either end, connects the aerial tuning inductance to the secondary of the jigger, the earth terminal of which is connected by means of the same type of flexible cable to the upper plate of the earth arrester. The lower plate of the earth arrester is connected by means of $\frac{7}{16}$ I.R.V.B. cable to an earth bolt. This latter is a hexagonal brass bar which is reduced and screwed at each end and supplied with nuts and washers. One end of it is screwed into a tapped hole in the iron bulkhead of the ship. If it be convenient to fix a nut on the end of the bolt projecting through the bulkhead this is done, but very often this end is un-get-at-able and the bolt is merely screwed tight home. The length of the bolt enables it to pass through the thickness of the wood lining of a cabin and still leave the inner end accessible for making the required connection to the earth arrester. The two terminals on the baseboard of the tuning lamp are connected to two points, about 6 ft. apart, on the wire connecting the earth terminal of the jigger to the upper plate of the earth arrester.

The aerial and its accessories will be dealt with in a separate chapter, at the end of which instructions for tuning will be found.

Short Wave Condenser.—In cases where the aerial is so long that its natural frequency does not admit of a wave length of 300 metres without taking out too many turns of the jigger secondary, a condenser is connected between its lower extremity and the upper plate of a separate earth arrester spark gap.

The following explanation may help to make clear the use of this extra condenser.

If the two circuits shown in Fig. 109 have the same frequency, the oscillation constants are equal, or—

$$\sqrt{LC} = \sqrt{L_1 C_1}$$

Fig. 109.—Two Separate Closed Circuits.

If the two circuits be now joined, as in Fig. 110, the total capacity of the condenser is equal to the sum of

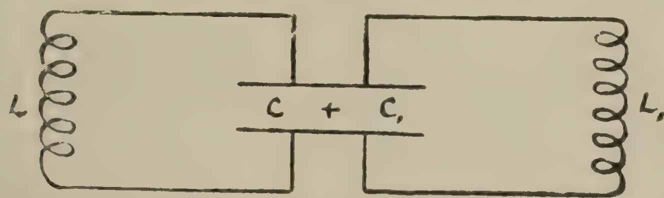


Fig. 110.—Same Circuits as in Fig. 109 joined in parallel.

separate capacities; or, taking a very simple case in which the capacities and inductances in each circuit are equal, the capacity of the second arrangement becomes $2C$.

The inductances L and L_1 are in parallel, and consequently only half the total current passes through each. If L is equal to L_1 (as must be the case if C equals C_1 and the two circuits possess the same frequency), the total inductance becomes $\frac{L}{2}$ and the oscillation constant for the circuit is

$$2C \times \frac{L}{2} = \sqrt{LC}$$

In short, if two circuits of the same frequency be joined as shown, the resultant circuit still possesses the same frequency. In the case quoted two closed circuits have been dealt with.

If A represents an aerial with a natural frequency fitting it for the production of a fairly long wave, the insertion of a condenser, C, at its lower extremity will reduce the total capacity and render it suitable for the production of a shorter wave. The aerial may be con-

sidered as a condenser possessing capacity in virtue of its position with respect to the earth, and the whole circuit may be drawn as shown in Fig. 111.

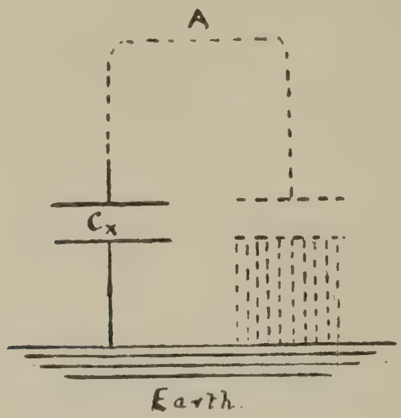


Fig. 111.—Aerial Circuit with Condenser in Series.

By suitably fixing the value of the condenser, Cx, the aerial circuit may be tuned to a 300-metre wave.

The other half of the condenser may now be adjusted so that when connected across the jigger-secondary it forms another circuit giving a 300-metre wave. Fig. 112 shows the circuit completed through the earth, but in practice the wires may be joined at the earth-arrester during the test.

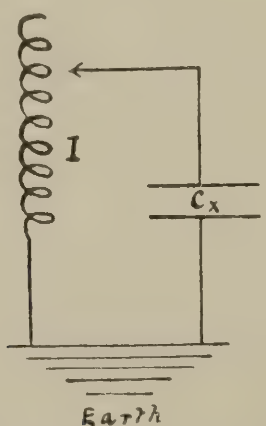


Fig. 112.—Jigger Secondary with Condenser in Series.

Also, in Fig. 112 the condenser is made equal to the first half, Cx, and the circuit adjusted to 300 metres by using more or less inductance. It is better, however, to use the

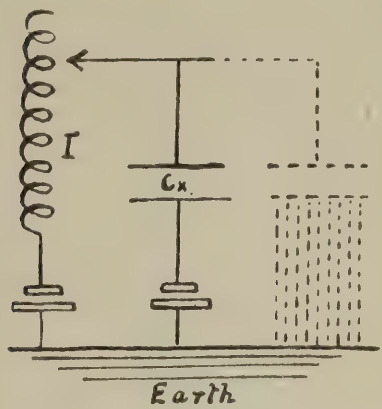


Fig. 113.—Combination of Figs. 111 and 112.

jigger-secondary, neither more nor less, and to adjust by altering the second half of the condenser.

The two 300-metre circuits thus obtained may be joined together just as in Fig. 110 by putting the two halves of the condenser in parallel and connecting aerial and earth as shown in Fig. 114. The complex circuit thus formed will still radiate a 300-metre wave, which will be excited in it by the action of the jigger-primary on the jigger-secondary.

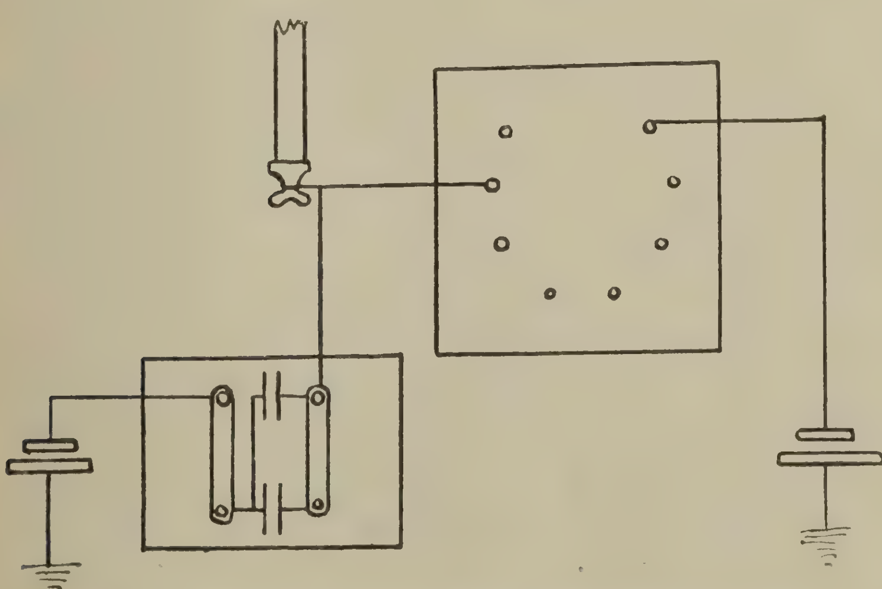


Fig. 114.—Open Radiating Circuit (Short Wave Adjustment).

Use of Separate Arresters.

It is seen that separate earth arresters are used, and the reason is fairly obvious. If only one arrester were used the arrangement would be as shown in Fig. 115. In

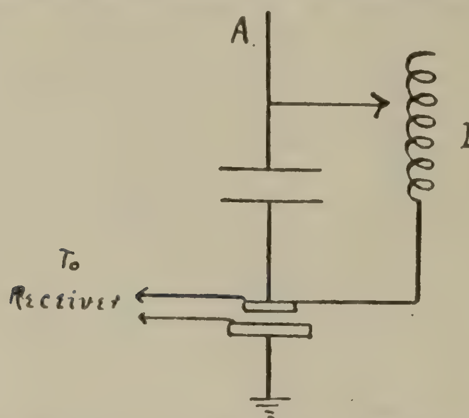


Fig. 115.—Same as in Fig. 114, but Incorrectly Connected to one Arrester.

this case a closed oscillating circuit consisting of the whole condenser and I is formed, and in the event of received currents possessing the same frequency as this circuit they would oscillate in it instead of passing through the receiver to earth.

The short wave condenser is of the same type as the main condenser, but it has to be specially built up to the capacity required for the particular aerial with which it is to be used. (See paragraph on Tuning Short Wave Transmitting Apparatus.)

Receiving Apparatus.—The receiving circuit includes the magnetic detector, the multiple tuner, a pair of telephones, and a telephone condenser.

The Magnetic Detector.—This instrument is shown in Fig. 116. A and B are two ebonite discs grooved round

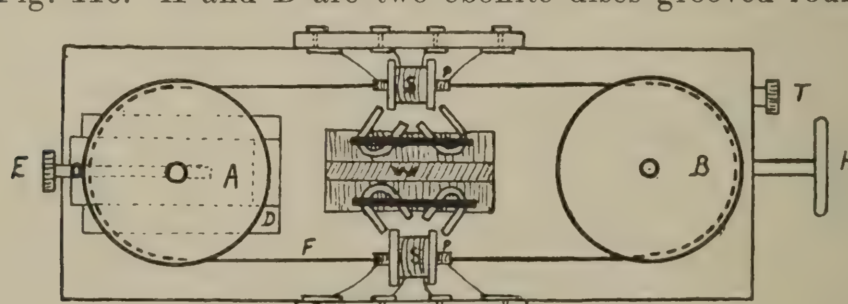
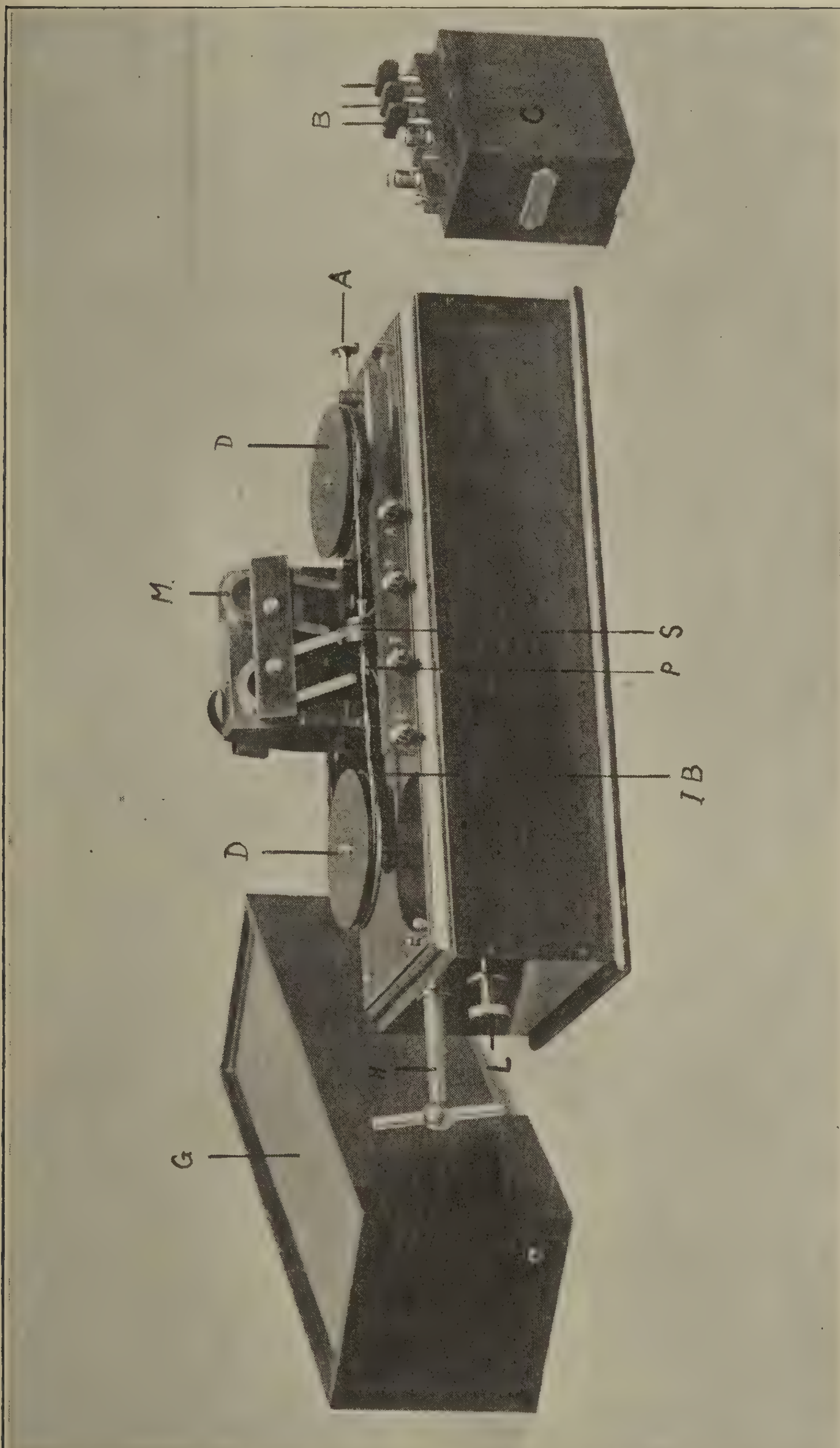


Fig. 116.—Magnet Detector.



MAGNETIC DETECTOR.

A. Adjusting screw for varying tension of iron band.—B. Telephone condenser plugs.—C. Telephone condenser.—D. Ebonite discs.—G. Glass-fronted cover.—H. Winding handle for clockwork.—IB. Iron band.—L. Clockwork control.—M. Magnet.—P. Primary coil.—S. Secondary coil.

the peripheries, B being mounted on a spindle forming part of a clockwork driving mechanism contained in the body of the instrument, and A being mounted on a brass plate, C, capable of sliding along a bed piece, D. The adjustment is effected by turning the screw, E, which is used to put the necessary tension on a continuous band of stranded soft iron wire, F. This band is made up of 70 strands of No. 40 S.S.C. (single silk covered) iron wire twisted into the form of a small rope and is rotated by the clockwork at the rate of about 1·6 metres per minute. This band passes through the centres of two sets of coils, the primaries being marked P and the secondaries S. The ends of these coils are connected to four terminals on each side of the instrument, the secondary winding being connected to the inner pair of terminals in each case. Between these two sets of coils a wooden block, W, carries four horseshoe magnets, two on either side. The usual position of the magnets with respect to the coils is shown in Fig. 117a, where it is seen that the like poles are together. This arrangement results in a slight

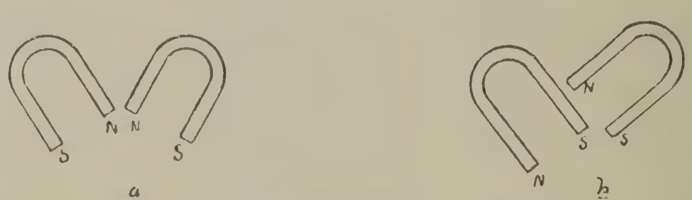


Fig. 117.—Detector Magnet Arrangements.

hissing sound being produced in the telephones all the time the band is moving. If the magnets be rearranged, as in Fig. 117b, this hissing or breathing effect is eliminated and at the same time the sensitiveness of the receiver is slightly lessened. The matter of arrangement is largely a matter of personal choice. Many operators claim that the breathing effect renders the reading of very weak signals difficult and that the latter arrangement is the better. Personally we prefer the former arrangement, because we are unable to agree with those who claim the breathing to be an obstacle in the way of the reception of weak signals, whilst the cessation of the breathing at once indicates that the clockwork has run down or that the band has stopped from some other cause.

H is the handle for winding up the clockwork, which will drive the band round for an hour and three-quarters for one winding-up. The clockwork is specially designed for even and silent running. Means of stopping or starting the clockwork is provided by the brass knob, T.

The primary windings are over small glass tubes and are made of No. 36 D.S.C. (double silk covered) copper wire. They are wound for a distance of about 2 centimetres over the tube, this giving them a resistance of between 2 and 3 ohms. Each secondary coil is wound on an ebonite bobbin to a resistance of about 140 ohms, which is about the same resistance as that of the telephones which are used with the detector. The action of the magnetic detector has already been explained. Only one side is used at a time, the second set of coils and magnets being provided as a stand-by in case of a breakdown in the other set. The primary terminals are connected by means of a bare No. 10 copper wire to the terminals marked "Detector" on the multiple tuner.

The Multiple Tuner.—This instrument contains the variable inductance and capacity for the aerial receiving circuit, the whole of an intermediate circuit, and the variable inductance and capacity for the detector tuning circuit. The inductance coils are contained in a teak box with an ebonite top and front. On the top three disc condensers are disposed, one being for each circuit. A two-way change-over switch and a micrometer spark-gap are also mounted on the top. To the left-hand side of the front of the instrument an ebonite handle, carrying a brass arm capable of rotation over a set of brass studs set in the form of a circle, enables the inductance in the aerial circuit to be adjusted. To the right of this handle a similar one is provided, which is so connected by means of ebonite coupling strips to three brass arms that these arms may be moved simultaneously over three sets of brass stops, thus enabling proportionate adjustments to be made in each of the three circuits with a single movement. This is called the Tuning Switch. Each of the two handles are calibrated, the aerial inductance being marked in microhenries and the tuning switch showing the limits of the receivable wave-lengths on the respective stops. On the

right-hand end of the instrument a third ebonite handle is mounted, called the intensifier handle, marked through one quadrant on its periphery in degrees. This handle is used to vary the relative positions of the inductances in the intermediate circuit with respect to the inductances in the aerial and detector circuits, or, as already explained, to vary the coupling between the circuits.

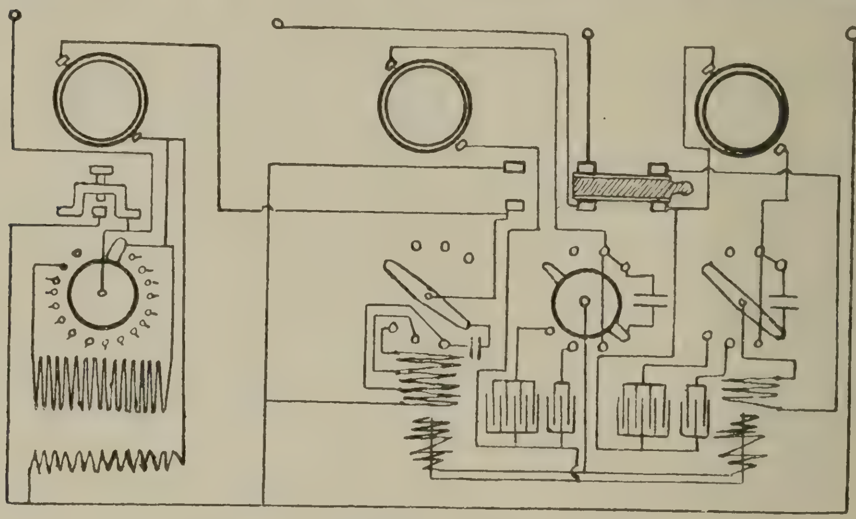


Fig. 118.—Multiple Tuner Connections.

The internal connections are shown in Fig. 118, but in order to understand more easily the different circuits a less involved drawing is given in Fig. 119.

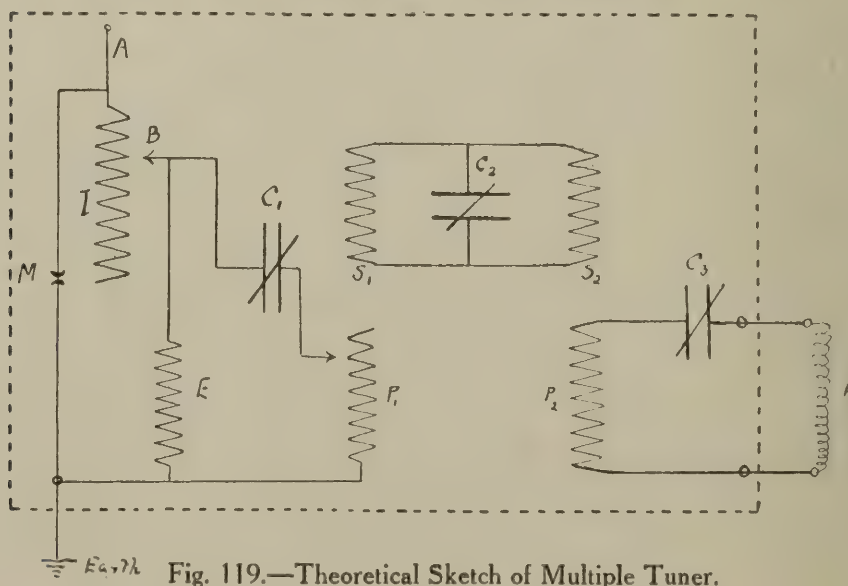


Fig. 119.—Theoretical Sketch of Multiple Tuner.

The aerial circuit consists of the aerial, the variable inductance, I, the variable condenser, C_1, and the variable inducing inductance, P_1, and a connection to earth, E. From the junction of the aerial and the inductance I a lead is taken through a micrometer spark-gap, M, to earth, and from the junction of the inductance I and the variable condenser C_1 a coil of high inductance value (of the order of 80,000 microhenries) affords a second path to earth. The use of this gap and inductive shunt is to prevent the accumulation of a heavy static charge on the aerial. Small charges leak to earth through the shunt coil, and heavy, sudden charges jump the spark-gap to earth, this being a path of less resistance and impedance than the path through the oscillating circuit. The inclusion of these circuits in the apparatus is necessary to protect the aerial tuning condenser from being broken down and the inductance coils from being burnt out. A section of the micrometer spark-gap is shown in Fig. 120.

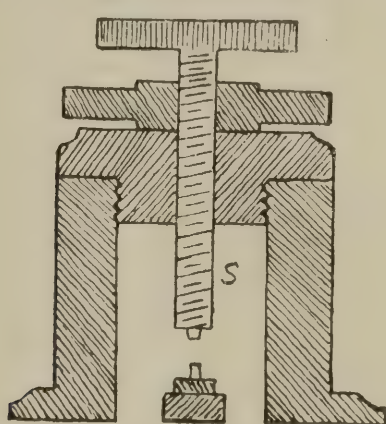


Fig. 120.—Section of Micrometer Spark Gap (Multiple Tuner).

The pitch of the thread on the screw S is such that one complete revolution moves the contact through one-hundredth of an inch. The screw has a left-handed thread and may be set by screwing S down until the contacts meet and then giving it one complete turn back.

The intermediate circuit consists of the two fixed inductances, S_1 and S_2, joined in parallel across the variable condenser, C_2. The detector circuit consists of the fixed inductance, P_2, the variable condenser, C_3, and the primary winding of the magnetic detector shown

outside the dotted line enclosing the different parts of the tuner at R (Fig. 119).

A variation of the aerial tuning inductance handle changes the point in I at which the tapping B is taken off.

A variation of the position of the intensifier handle

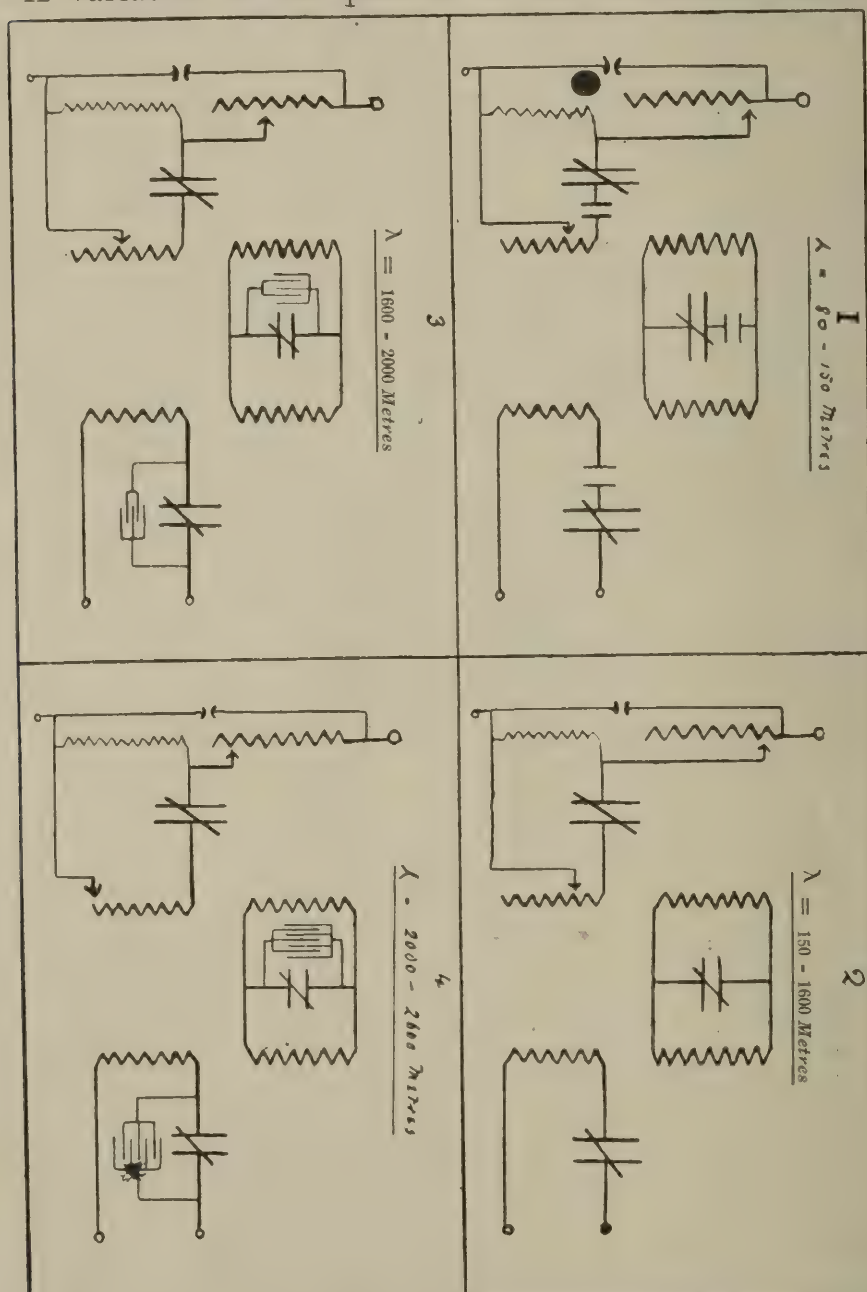


Fig. 121.—Connections of M.T. for Various Adjustments.

alters the position of the coils S_1 and S_2 with respect to the coils P_1 and P_2, and an alteration of the tuning switch handle produces variations in each circuit as shown in Figs. 121, 1, 2, 3, and 4.

With the tuning switch on the first stop a small block condenser is placed in series in each circuit, thus reducing the capacity in each to dimensions suitable for the reception of short waves. On the second stop these small block condensers are cut entirely out of each circuit. Contact with the third stop introduces inductance in the aerial circuit and places small block condensers in parallel with the variable condensers in the intermediate and detector tuning circuits, thus providing for the reception of longer waves. The fourth stop increases the value of this added inductance and capacity. The wave-ranges for the respective stops are given in the diagrams. A careful consideration of the more complicated diagram of the actual connections will show how the simplified drawings have been made. The switch on the top of the instrument is used to change over from a "stand bi" position, when waves of widely varying length are audible, to a "tune" position, which is done when it is desired to cut out other signals which may be interfering with reception. A simple diagram showing how this switch is connected is shown in Fig. 122. It is seen that on the "stand bi" side the magnetic detector is directly

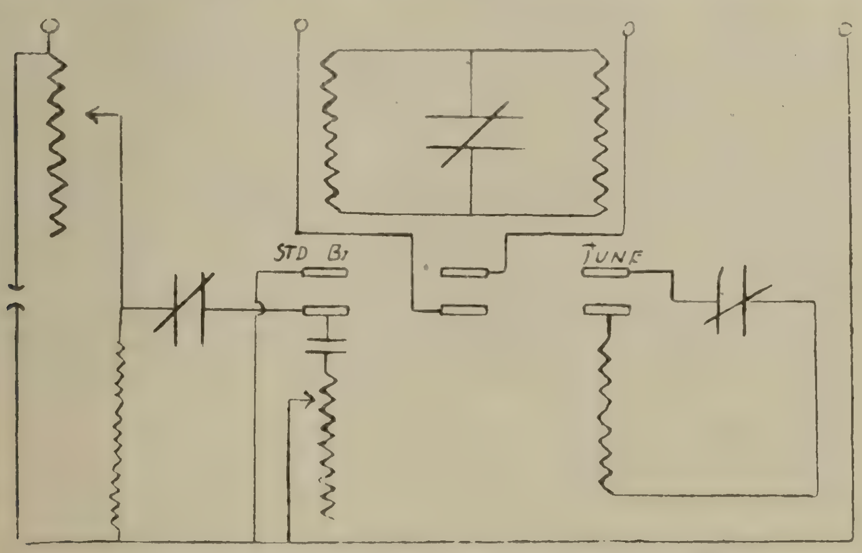


Fig. 122.—Change-Over-Switch Connections M.T.

in the aerial circuit, and that the operation of throwing over the switch places it in the detector circuit.

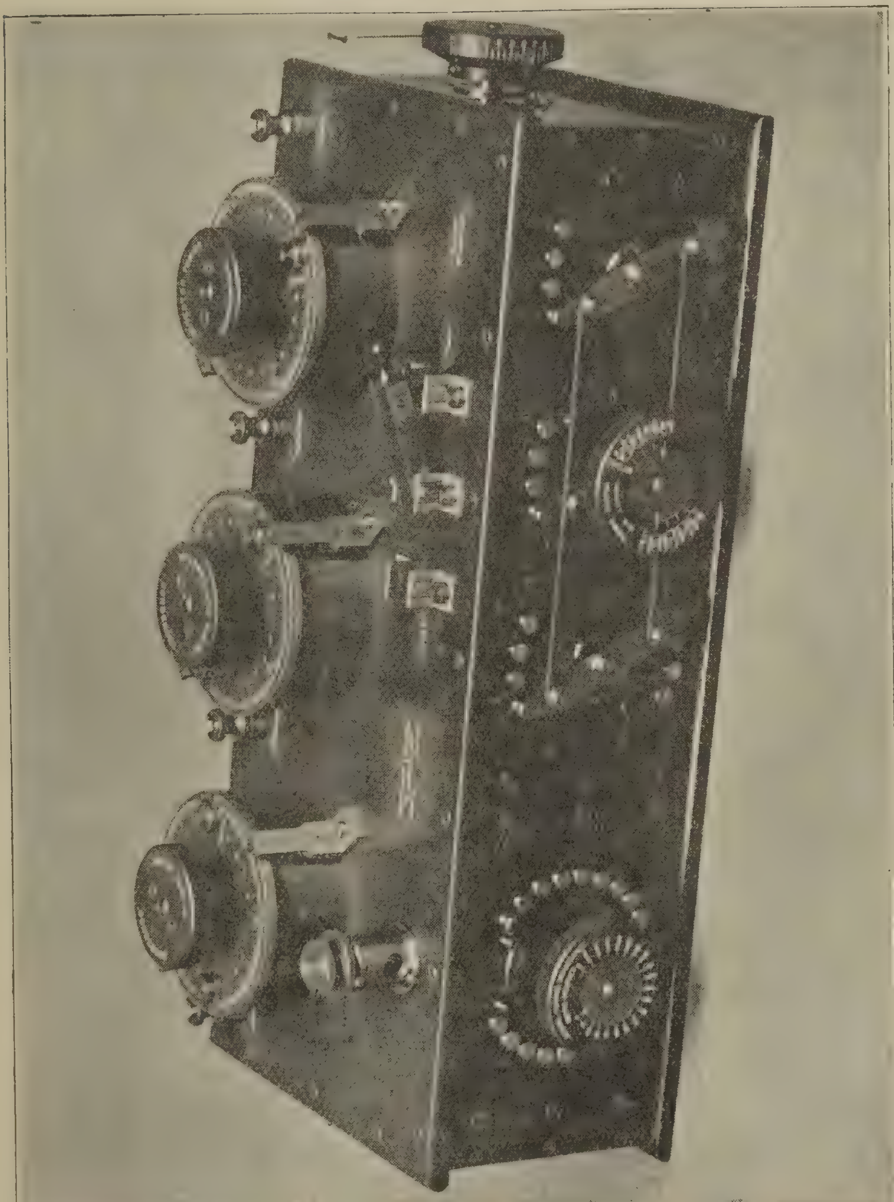
The tuner is designed for a range of from 300 to 8,000 feet. If the capacity of a standard Leyden jar be taken as 1,000 centimetres, the maximum capacity of each of the three variable condensers is ten jars. A scale on the top of each condenser is marked accordingly, and is subdivided into divisions of one-tenth of a jar. The block condensers placed in circuit by means of the tuning switch increase the capacity in the intermediate and detector circuits to a maximum of 30 jars. If the capacity be reckoned in jars and the inductance in microhenries, the formula for the calculation of wave length in feet is

$$\lambda = 206\sqrt{\text{jars} \times \text{microhenries}}$$

As already stated, the two terminals marked "Detector" are connected to the ends of the primary of the magnetic detector. Two other terminals with which the top of the instrument is provided are marked "Aerial" and "Earth," and are connected by means of $2\frac{1}{2}$ ampère flexible wire to the upper and lower plates respectively of the earth arrester spark-gap.

The use of the arrester is now apparent. The received currents being extremely weak are unable to break down the air resistance of the small gap, and run to earth through the whole of the receiving circuit. The powerful currents developed in the aerial during transmission are at a high enough voltage to jump this small gap, the latter offering much less impedance than is offered by the coils in the receiving circuit. It is seen, therefore, that the arrester obviates the necessity for a switch for the purpose of changing over from sending to receiving; or perhaps it would be better to state that it acts as an automatic switch for this purpose.

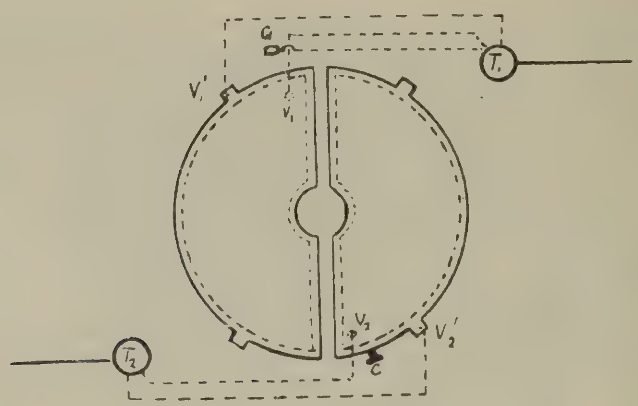
Disc Condenser (Variable).—The variable condensers mounted on the multiple tuner are of the most compact form in existence, a variable capacity up to ten jars, or 10,000 centimetres, being contained in a flat cylinder 4 inches in diameter and $1\frac{3}{4}$ inches in height. The conductors consist of two sets of interleafing zinc vanes, and the dielectric consists of a number of thin circular sheets of ebonite. The alternate vanes in each set are held in



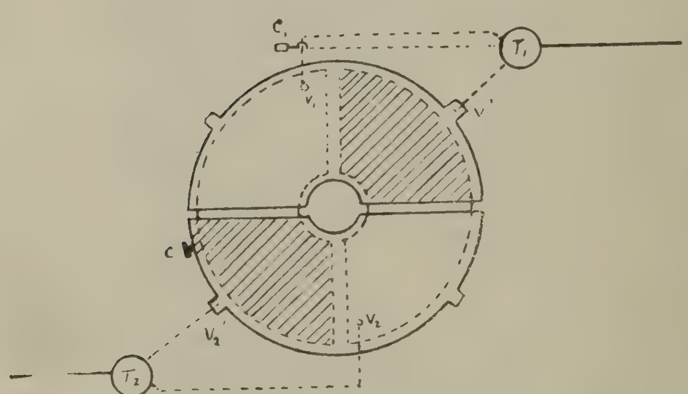
MULTIPLE TUNER.

I. Intensifier handle.—L. Lock nut.—M. Micrometer spark-gap.—S. Adjusting screw.

a fixed position in the container, whilst the other alternate vanes are all capable of being turned through 180 degrees by the movement of an ebonite handle mounted on the top of the cylindrical container. Figs. 123 (a)



(a)



(b)

Fig. 123 (a) and (b).—Disc Condenser Explanatory Sketches.

(b) and (c) show the disposition of the movable vanes with respect to the fixed vanes for capacities of zero value, half the total value and the total value respectively. T_1 and T_2 are the main terminals of the condenser, the former being permanently connected to the movable vanes at V'_1 and to the fixed vanes at V_1, while the latter is connected to the movable vanes at V'_2 and to the fixed vanes at V_2. In Fig. 123 (a) it is seen that the opposing vanes of the right-hand bank are all con-

nected to the terminal T_2, the opposing vanes of the left-hand bank being connected to the terminal T_1. Thus the capacity of the condenser in this position is practically zero, the effect across the opposing edges of the vanes along the centre being negligible. If the vanes V'_1 and V'_2 be moved together into the position shown in Fig. 123 (b), it is found that parts of the opposing plates are connected respectively to the terminals, the areas of the opposing portions being shaded in the figure. If the moving vanes be taken through another 90 degrees, as shown in Fig. 123 (c), it is seen that the whole areas of

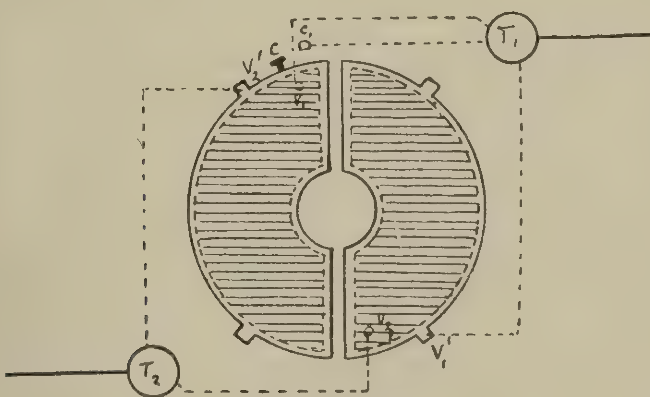


Fig. 123 (c).

opposing vanes are actively connected respectively to the two terminals. This, of course, means that the condenser has a maximum capacity, and it is easily seen that a condenser of this type is continuously adjustable, so that extremely small variations of capacity may be obtained.

A brass contact piece, C, is attached to the movable vanes, and if the handle be turned a little beyond the maximum capacity point C makes contact with a stop, C_1, which is permanently connected to the terminal T_1, thus shorting the condenser.

The Telephone Condenser.—In this condenser sheets of tin foil are used as conductors, the alternate sheets being separated from each other by a mica dielectric. The condenser is divided into three parts, varying amounts being placed in the circuit by means of brass plugs and sockets. A sketch of the connections is shown in Fig. 124. A, B, C, D and E are brass blocks disposed

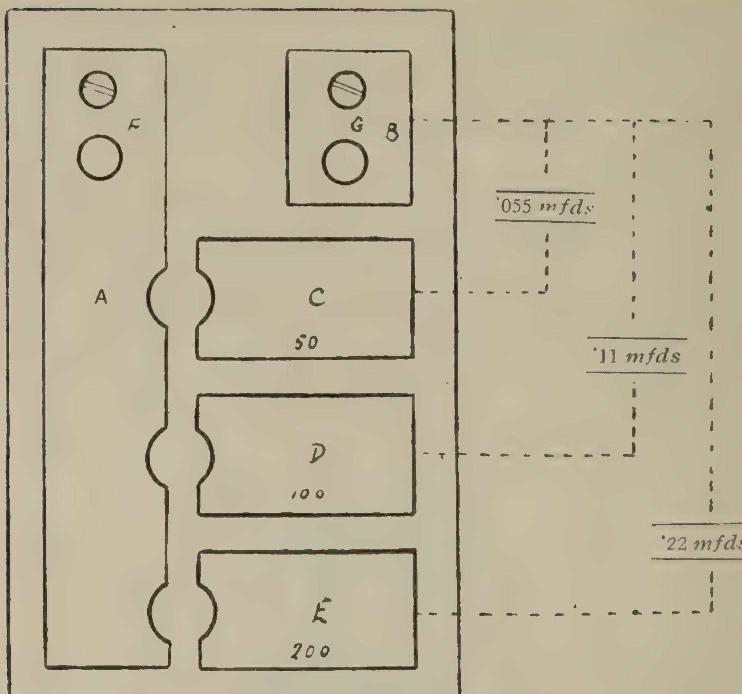


Fig. 124.—Telephone Condenser.

on the ebonite top of a teak box as shown. Three condenser groups of ·055, ·11 and ·22 microfarads respectively are fixed by means of paraffin wax in slots cut in a wooden block. One side of each group is connected to the block B, the other sides being connected respectively to C, D and E. Three brass plugs are provided by means of which any separate condenser or combination of condensers may be joined across the terminals FG. Seven different values are thus obtainable. The capacity is large in comparison with the outside dimensions of the instrument, because, as it has to stand only low pressures, the distance between the conductors or the thickness of the dielectric need only be small, thus allowing for the placing of a large number of sheets providing a large area in a small space. The terminals of this condenser are connected to the secondary terminals of the magnetic detector by means of $2\frac{1}{2}$ ampère flexible wire, and its use is to alter the tone of the signals in the telephone according to the taste of the operator, and to put the telephones in their most sensitive condition.

The Telephones are also connected either to the ter-

minals of the condenser or to the secondary terminals of the detector.

A brief explanation of the telephone is here necessary. Sound is a sensation excited in the ear by the vibratory motion of bodies.

If a flat steel spring be fixed in a vertical position in a vice, as shown in Fig. 125, and the free end of it be

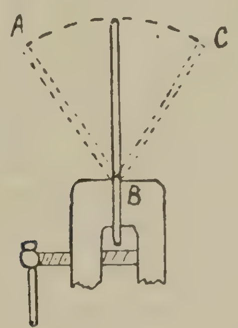


Fig. 125.—Production of Sound Waves.

displaced so that it takes up the position shown by the dotted line AB, on releasing it a vibratory motion will follow. The end A will pass backwards and forwards along a gradually decreasing arc, AC. During its first movement to the right it compresses the air on its right-hand side, and causes a state of rarefaction on its left-hand side. A reverse movement has exactly the opposite effect. As long as the spring continues to vibrate waves of rarefaction and compression are propagated, the frequency of these waves or the number of complete vibrations per second determining whether they are audible or not. If the frequency be anything between 29 and 20,000 per second audible sounds are produced. The telephone is an instrument capable of producing waves in the air of such a frequency. A disc of thin soft iron, varnished to prevent rusting, takes the place of the spring just described, and it is set in vibration by fluctuations in the intensity of a magnetic field. Fig. 126 shows an electro-magnet with its two poles in close proximity to a disc of soft iron, D, which is firmly clamped in position by its edges. The core of the magnet is permanently magnetised and exercises a force of attraction on the disc. If a current be passed through

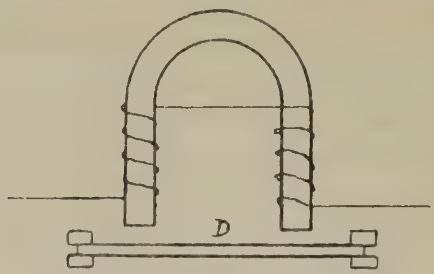
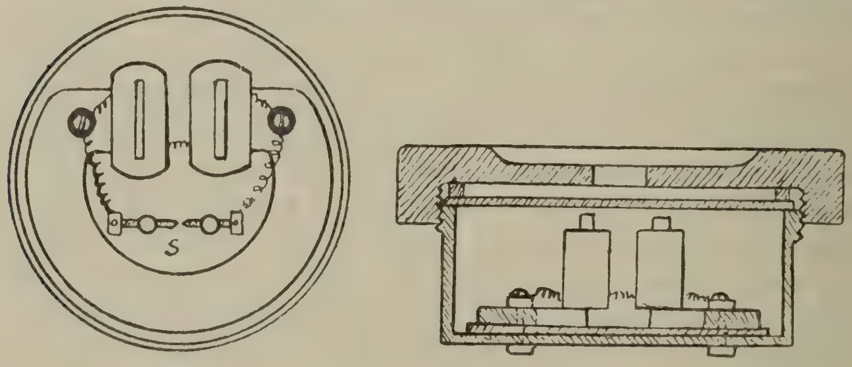


Fig. 126.—Theoretical Telephone.

the coils wound round its pole pieces, this force of attraction is increased or decreased according to the direction of the current. If the force be increased, the centre of the disc is pulled towards the magnet, and if the force be decreased it is released to some extent. If, then, rapid alternations of current or intermittent unidirectional currents be passed through the windings, the disc (or diaphragm, as it is called) is caused to vibrate; and if the frequency of the vibrations be within the limits stated above, they will produce the sensation of sound in the ear. Figs. 127a and 127b show a plan and



(*a*) (*b*)

Fig. 127 (*a*) and (*b*).—Plan and Section of Telephone (Watch Pattern).

section of the type of telephone receiver used in a wireless installation. On account of its shape, such a receiver is called a watch receiver. Two complete watch receivers are connected in series at the ends of a steel or aluminium spring to form the telephone head-gear. As the space available is very small, the wire used in the coils of the electro-magnets must of necessity be very thin, in order to be able to use the necessary ampère-turns required for the high degree of sensitiveness of the

telephone. In the low resistance telephones used in connection with the magnetic detector the wire is insulated with silk, but where a much greater number of turns is required, as in the case of the telephones of from two to eight thousand ohms resistance used with a valve receiver, the insulation usually consists of a coating of enamel, as space is thus economised. In the high resistance telephone a pair of protective spark points is often included, as shown in Fig. 127 at S. Thus, if the current reaches a value too great for the coil windings, a discharge takes place across the points, thus preventing burning of the coils. Again, where enamelled wire is used, the interior of the case is filled with paraffin wax further to ensure good insulation.

Short-Circuiting Device.—Two leads of $2\frac{1}{2}$ ampère flexible wire are taken from the two brass springs fitted with contacts, already mentioned as being mounted on the manipulating key, either to the telephone condenser or to the secondary terminals of the magnetic detector. If the main break of the key and the break between the two small contacts be properly adjusted, the latter will short-circuit the telephone just before the condenser in the transmitting circuit discharges, thus preventing the loud sounds of the transmitted signals being heard in the telephones. This prevents the telephones or the operator's ear being rendered insensitive. At the same time it is possible during the intervals between each transmitted dot and dash to detect any effort on the part of the corresponding station to ask a question.

Adjustment of Receiving Circuit.—When not in actual communication with any particular station, the operator always listens with the change-over switch on the "stand bi" position. With an aerial of normal length he "stands bi" with the aerial tuning condenser shorted, and with none of the aerial tuning inductance in the circuit. If the aerial be a long one a certain amount of condenser is used when standing "bi," and if it be a short one a certain amount of inductance is necessary in the circuit. Very often an adjustment of the aerial inductance and capacity is all that is necessary to render the required signals distinct from any others which may be audible. In cases where considerable interference or

"jamming" is met with, the aerial circuit must be tuned as nearly as possible and the switch thrown over

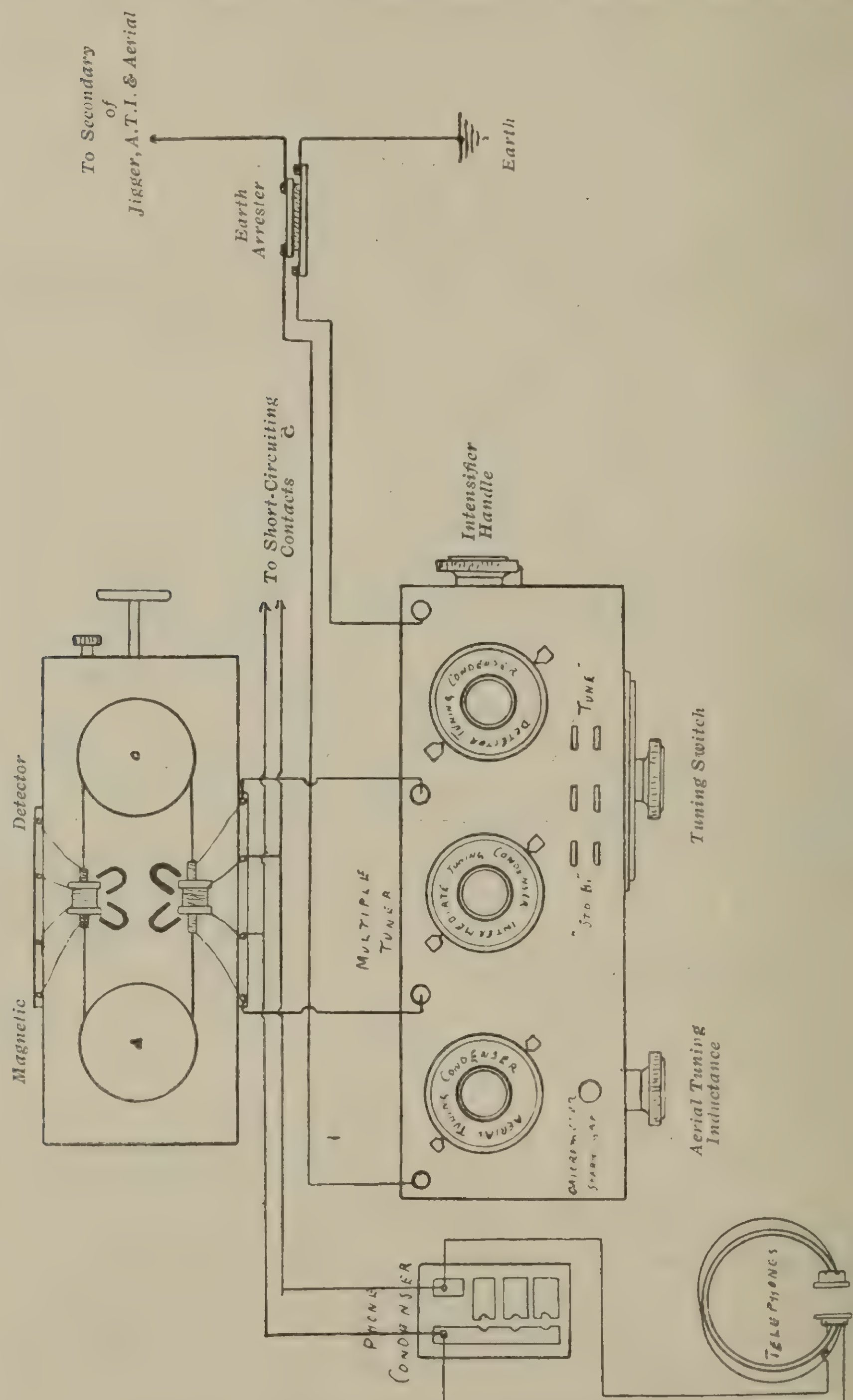


Fig. 128.—Receiving Circuit Connections 1½ K.W. Set.

on to the "tune" side, care being taken that the intensifier handle is indicating an angle of 90 degrees. The tuning switch must then be placed on the particular stop corresponding with the wave length to be received, the stop being indicated by the amount of inductance and capacity in the aerial circuit. The intermediate and detector condensers must then be varied together until the maximum strength of signals is obtained. It is very important that these two condensers should be varied together, otherwise the operator may spend a considerable time before hearing any signals at all on the tuned side. A further slight re-adjustment of the aerial tuning condenser may then be found to be necessary, and if interference is still troublesome, the coupling between the three circuits may be loosened by means of the intensifier handle. As the latter indicates an angle more nearly approaching zero the whole apparatus is found to become more selective. That is to say, very fine adjustments become necessary, and freedom from interference is more pronounced. The diagram of the complete connections of the receiving circuit is shown in Fig. 128.

Measurement of Received Waves.—The multiple tuner may be used for measuring the length of the received waves as follows:

Tune for the received signals as already described. Then gradually decrease the coupling by turning the intensifier handle as near ten degrees as possible. *Each slight decrease of the coupling requires a slight readjustment of the variable condensers.* If the signals are still audible with the intensifier handle at ten degrees, the wave length may be read off at once from a calibration table supplied with each instrument. As the only variable part of the intermediate circuit is the condenser, it is plain that the oscillation constant and the wave length will depend directly on the value of this condenser, and the table supplied gives the wave lengths corresponding to the various values of this condenser when used in connection with any particular stop of the tuning switch.

An example of a calibration table is given in Fig. 129. If the intensifier handle cannot be turned down to ten degrees, the reading must be taken when it is as near ten

TABLE OF WAVE LENGTHS CORRESPONDING TO READINGS OF INTERMEDIATE CONDENSER — WHEN INTENSIFIER HANDLE INDICATES AN ANGLE LESS THAN 10° —

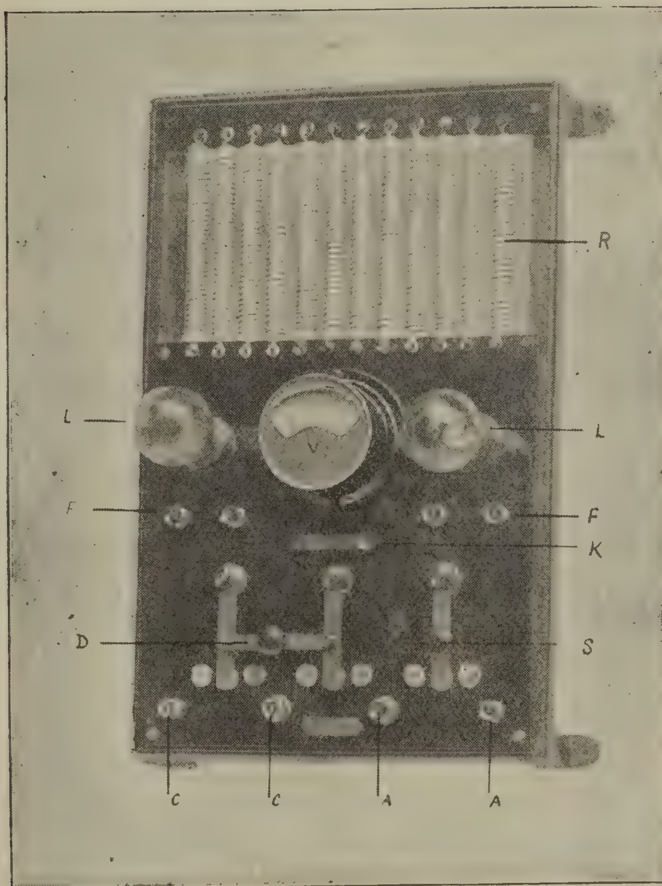
WAVE LENGTH IN METRES.	TUNING SWITCH AT	INTERMEDIATE CONDENSER AT	WAVE LENGTH IN METRES.	TUNING SWITCH AT	INTERMEDIATE CONDENSER AT	WAVE LENGTH IN METRES.	TUNING SWITCH AT	INTERMEDIATE CONDENSER AT
80	80/150	0 10	300.	150/1600	0 75	900.	150/1600	3 27
90.	"	0 27	325.	"	0 81	1000.	"	3 90
100.	"	0 36	350.	"	0 87	1100.	"	4 60
110.	"	0 45	375	"	0 94	1200	"	5 37
120.	"	0 54	400	"	1·00	1300.	"	6 20
135.	"	0 70	450.	"	1 16	1400.	"	7 10
150.	150/1600	0 46	500.	"	1 32	1500	"	8 13
165.	"	0 48	550.	"	1 48	1600.	1600/2000	1 70
180.	"	0 50	600.	"	1 67	1700	"	2 93
200	"	0 54	650.	"	1 90	1800.	"	4 14
220.	"	0 58	700.	"	2 14	2000.	"	6 73
240.	"	0 62	750.	"	2 39	2200.	2000/2600	1 00
260.	"	0 66	800.	"	2 67	2400.	"	4 14
280	"	0 70	850.	"	2 97	2550.	"	6 65

MULTIPLE TUNER No. 28610

Fig. 129.—Calibration Table.

as possible; this, however, only giving an approximately accurate result.

Measurement of Transmitted Waves.—By connecting a loop of wire between the earth and aerial terminals of the tuner, it may be used to measure the length of the transmitted wave as follows. With the intensifier at an angle of ten degrees the tuner and magnetic detector are set up outside the cabin at some small distance from the aerial, the former being adjusted for reception as explained above. If the signals are inaudible with a ten-degree adjustment, the loop of wire between the earth and aerial terminals must be increased until good signals are obtained. The wave length is obtained from the calibration curve as before.

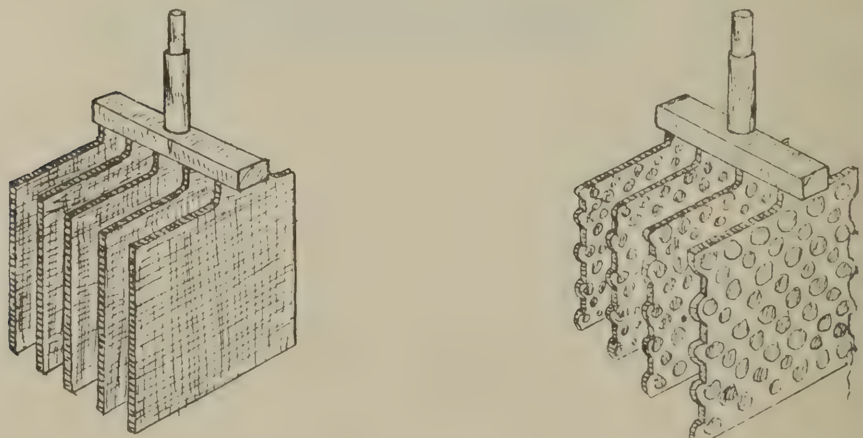


MARINE TYPE SWITCHBOARD.

A. Accumulator battery terminals.—C. Coil circuit terminals.—D. Double pole switch.—F. Fuse terminals.—K. Voltmeter key.—L. 50 c.p. lamps.—R. Charging resistance.—S. Single pole switch.—V. Voltmeter.

The Emergency Transmitting Apparatus.—A second set of transmitting apparatus is usually fitted in conjunction with the $1\frac{1}{2}$ K.W. set described. This comprises an accumulator battery with a suitable charging switchboard and a ten-inch induction coil. Arrangements are made whereby the coil can be quickly placed in connection with the aerial for the production of a plain aerial spark. The advantage of this type of transmission in cases of emergency is that the receiving circuits of stations not strictly in tune are affected by the highly damped waves. A separate manipulating key is used in connection with this gear, differing from the other in that it is not supplied with the short-circuiting contacts.

The Accumulator Battery and Marine Type Switchboard.—The accumulator battery consists of eight "Chloride" secondary cells. It is used to supply current to a ten-inch induction coil, which has a primary winding of a resistance of about half an ohm. The ordinary working current taken by this coil is about eight ampères, hence the necessity of using eight cells in order to obtain the necessary E.M.F. of sixteen volts. Each cell contains



(a) *Negative* (b) *Positive*

Fig. 130.—Accumulator Plates.

five negative and four positive plates the respective groups appearing as shown in Fig 130a and b. The

cells are connected to a switchboard fitted with a resistance and carbon filament lamps, by which the voltage of the ship's current is regulated to the dimensions required for charging. This switchboard is also supplied with a single and a double pole switch. The former is used to connect up the coil to the circuit and the latter to connect up the accumulators to the charging dynamo.

In the general notes on accumulators it is stated that great care must be taken to connect the positive pole of the battery to the positive pole of the dynamo when charging. The above-mentioned lamps afford a simple means of recognising when such connections have actually been effected. If the double pole switch be placed in turn in each of its two possible positions it is seen that the lamps glow with two different degrees of intensity. The position of the switch at which the lamps glow *least* brightly is the correct position for charging. The position of the double pole switch determines the direction of the charging current through the battery.

On ships carrying more than one dynamo it sometimes happens that the mains are so connected that different polarity is given by one machine than is given by another. The use of the double pole switch is now apparent. It obviates any necessity to alter the switchboard connections of the battery, as a mere changing over from one position to the other produces a compensating reversal of the charging current. At the same time, it is evident that an operator should never leave a battery on charge when away from the room where such a change of polarity is possible. This switch is also useful in another way. When overhauling accumulators the connections may have been removed. With such a changing arrangement as that provided by the switch it is not a matter of much importance if the operator forgets which lead should be connected to any particular terminal on the board, since, if he should have accidentally reversed them, the glow of the lamps shows him in which position to leave the switch in order to rectify the change. The accumulator battery is not very largely used, and the arrangement of the charging resistance is such as to only allow of its being charged very slowly. The resistance is of four ohms, and the two

fifty candle-power carbon filament lamps, which are in parallel with each other and in series with the rest of the

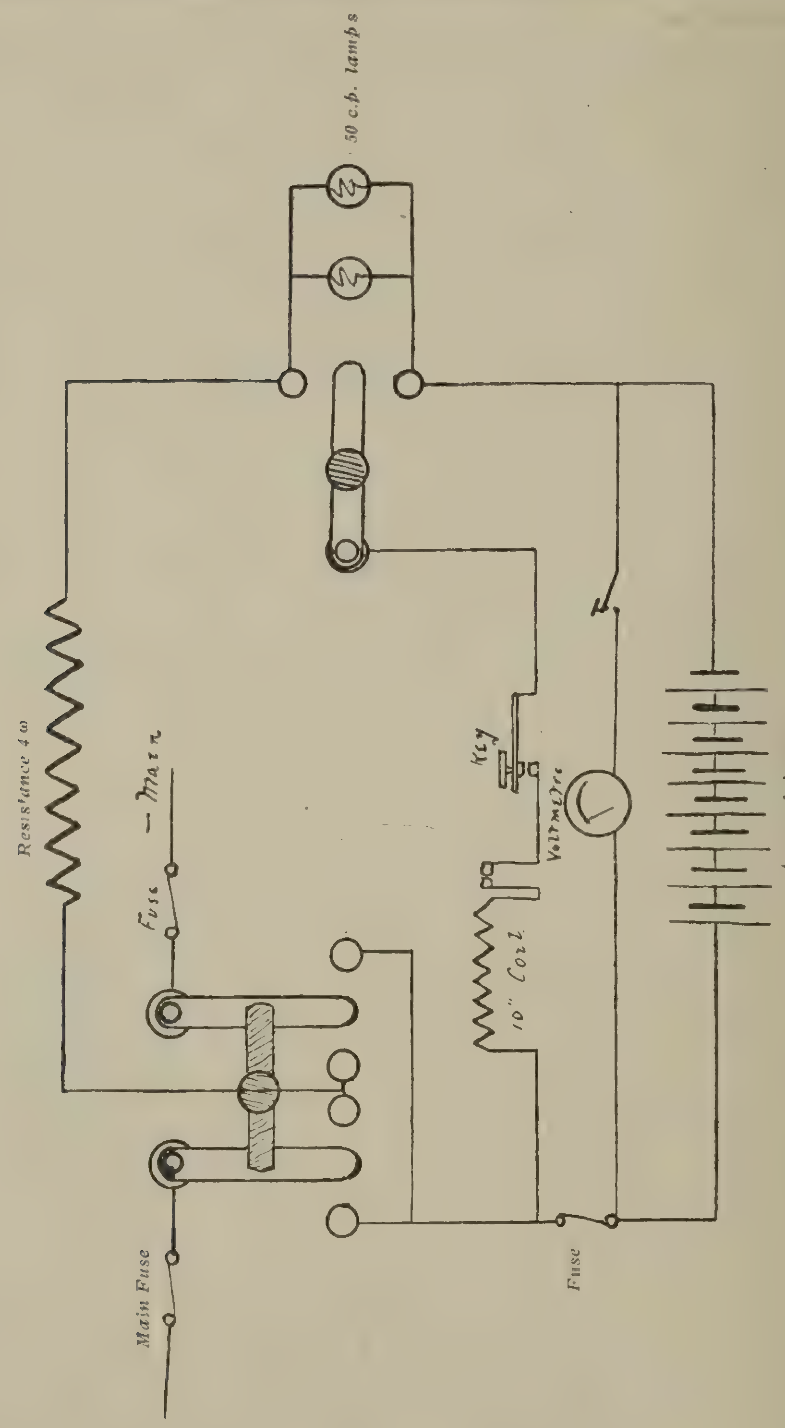


Fig. 131.—Emergency Transmitting Gear (Theoretical).

charging circuit, allow a charging current of about four ampères to pass. The normal charging rate of the battery as given by the makers is 12 ampères, so it will be seen that in order to keep it well charged up long charges must be given.

As there are eight cells the voltmeter with which the switchboard is supplied should give a reading of eight times 2·6 volts, that is 20·8 volts when the battery is fully charged with the charging current still passing. The specific gravity of the acid at this stage should be 1·215, and gas should be freely bubbling from both positive and negative plates. A little time after the charging current has been cut off the reading of the voltmeter should be about 17 volts, or approximately 2·1 volts for each cell. As the voltage of a cell should never be allowed to fall below 1·85 the total voltage as shown on the voltmeter should never fall below 14·5, and 15 is a much safer limit. The specific gravity of the acid should then be about 1·170.

If occasion arises to remove the plates from a cell in order to inspect them great care must be taken when replacing them to see that the pole pieces agree with the marks on the outside of the container. Care must also be exercised when replacing the covers that the positive and negative signs are adjacent to the corresponding poles. When disconnecting one cell from another care must be taken not to allow the flexible connections to short-circuit any cell. The switchboard connections are shown theoretically in Fig. 131, and actually in Fig. 132.

If it is impossible to obtain distilled water to replace that lost by evaporation, rain water or the cleanest water obtainable must be used, and care must be taken to see that it is free from sediment. On no account must acid be added in this case. In order to keep the battery in an efficient condition it is advisable to work from it at least for a short time each day.

A great deal of the disintegration of the plates so often found in the accumulators is due to operators allowing the battery to remain on charge from one end of a voyage to the other.

The lamps on the switchboard are not intended for lighting or heating purposes, and consequently when the

battery is fully charged the current should be cut off, as continued excessive overcharging merely causes furious

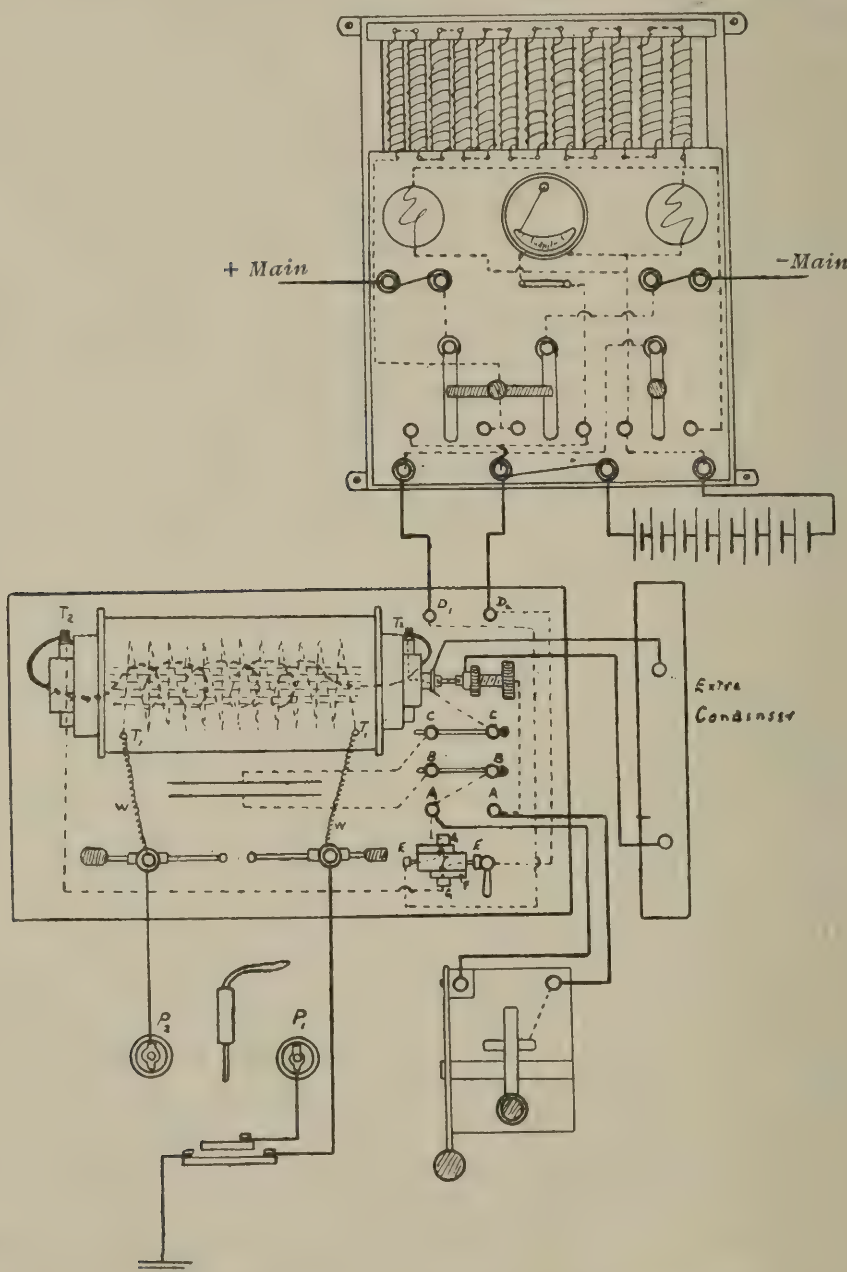


Fig. 132.—Emergency Transmitting Gear Connections.

bubbling, which, as has been previously explained, results in disintegration of the plates.

The capacity of the battery is 80 ampère hours, by which it is meant that a current of eight ampères may be taken from it for a period of 10 hours. If a heavier current be used the capacity in ampère hours is a little less, and if a smaller current be used it is a little more.

The normal charging current of 12 ampères takes about $7\frac{1}{2}$ hours to charge fully a battery which has been run down to its safety limit. This we see gives ninety ampère hours, so that the efficiency of the battery is represented

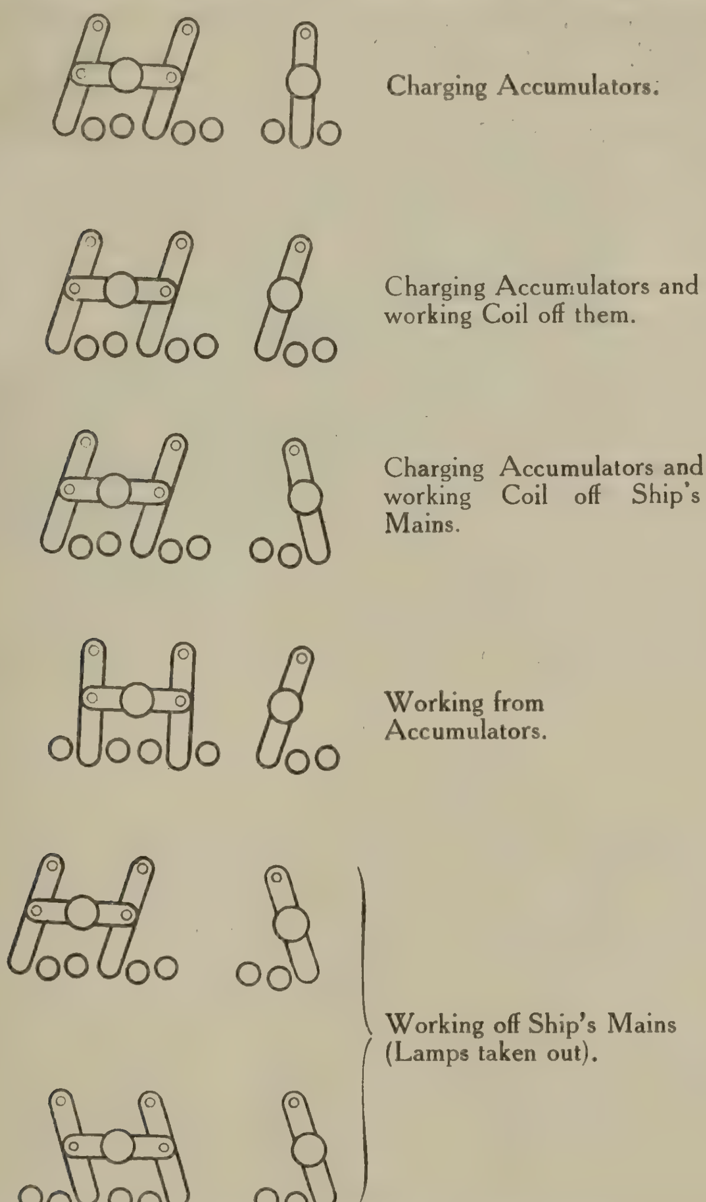
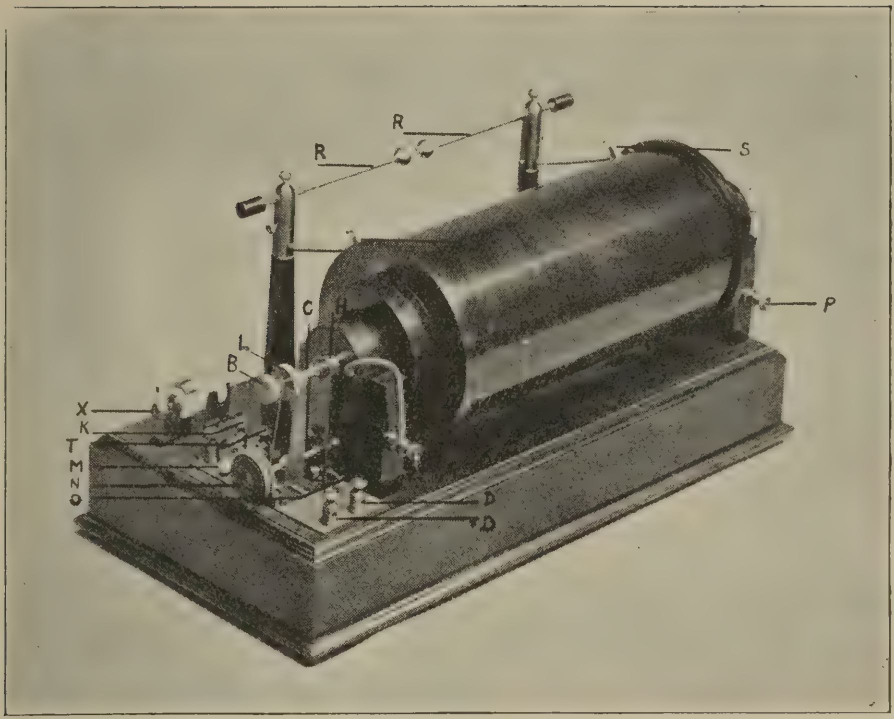


Fig. 133.—Switch Positions (Marine Type Switchboard).

by the ratio of 8 to 9, or, in other words, the battery is said to have an 88·8 per cent. efficiency. Several combinations of the two switches may be used for different purposes. Thus it is possible either to charge the battery alone, to charge the battery and work the coil from the main current, to work the coil from the battery current, or to work the coil from the main current. The different arrangements of the two switches are shown in Fig. 133, where it is presumed that the accumulator battery and coil are connected to the switchboard, as in Fig. 132.

E.P.S. Accumulators.—The E.P.S. type of accumulator is also sometimes installed in standard sets of apparatus. The general instructions given with respect to the "Chloride" type may be followed. The normal charging rate for the E.P.S. cells used is 10 ampères, instead of 12 as used for the "Chloride" accumulator. Of course, a battery is never composed of a mixture of both types.

The Induction Coil.—Fig. 133 shows the connections of the 10-inch induction coil. A primary winding of 358 turns of No. 12 enamelled and braided copper wire is wound over a core of stranded soft iron wire. The ends of this winding are brought through the ebonite ends of the casing in which the coils are contained, and are supplied with small brass thimbles by means of which connection may be made to two terminals, T_2, mounted on the ebonite supporting blocks. This arrangement facilitates packing for transportation, etc., as the coil may be easily removed from its base and separately packed. The core and primary winding are contained inside an ebonite tube, over which a secondary coil of 54,000 turns of No. 34 silk covered copper wire is wound. This secondary coil is wound in 116 sections, each section being contained in a former of insulated paper; one reason for this being that any breakdown can be more easily located and repaired. A more important advantage gained by this method of winding the secondary is that a high potential difference does not exist between any two adjacent turns, and therefore there is less risk of a breakdown of the insulation. The sections are connected in series, the two extreme ends being connected to two terminals, T_1, mounted on the



10″ INDUCTION COIL.

B. Back contact adjusting screw.—C. Platinum contacts.—D. Main terminals.—H. Hammer.—K. Manipulating key terminals.—L. Lock nut for break adjustment.—M. Condenser connecting pin.—N. Tension adjusting screw.—O. Terminals for extra condenser.—P. Primary winding terminals.—R. Discharge rods.—S. Secondary winding terminals.—T. Condenser terminals.—X. Commutator.

ebonite cylinder which encloses the coils. Brass discharge rods, each fitted with a small ebonite handle at one end and with a brass sphere at the other, are mounted on two ebonite supporting pillars and are connected to the terminals, T_1, through choking coils of fine insulated wire, W. A hammer break is employed, the construction of which is seen in Fig. 134. A vertical brass spring, S,

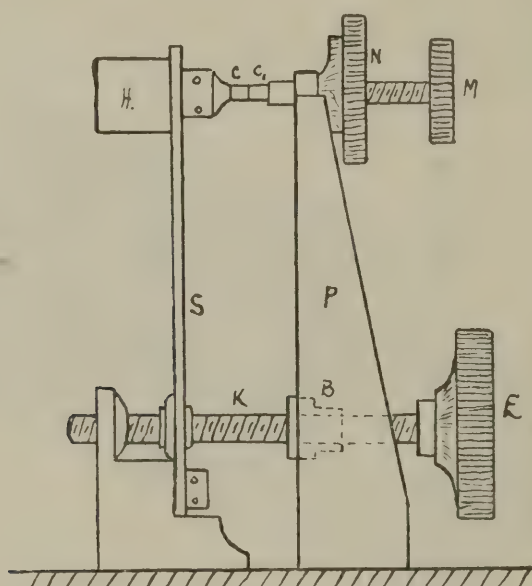


Fig. 134.—Hammer Break for Induction Coil.

carrying a soft iron hammer, H, at its upper extremity, is fitted with a platinum contact, C. A second platinum contact C_1 is mounted at the upper end of a brass supporting pillar, P, its position with respect to the first contact being adjustable by means of the screw, M, and lock nut, N. The tension on the spring, S, is adjusted by means of an iron pin, K, supplied with an ebonite handle, E, the pin passing through an insulating bush, B, fixed in the brass supporting pillar, P. When using this break, care must be taken that the faces of the contacts are in parallel relationship and thoroughly clean. They must be cleaned occasionally with a smooth file. The play of the hammer between the end of the core and the back contact is regulated by means of the screw M, and, with

a proper adjustment, the hammer will give fifty interruptions per second.

Two terminals, D_1 and D_2, are connected externally to the source of current supply and internally to the brass supporting pillars of the commutator. The commutator provides a means of altering the direction of the current through the primary winding. An ivory drum, I, is mounted on two brass supporting pillars, E, each pillar being connected internally to one of two brass contact pieces, which are placed on opposite sides of the drum. A small ivory handle is fixed at the right-hand end of the drum, by means of which the latter can be turned on the axis, EE. When this handle is in a horizontal position, as shown, the brass contact pieces, FF, are pressed hard against two vertical brass springs, GG. If the handle be turned through 180 degrees the positions of F and F are reversed, and by tracing out the circuits it is seen that the direction of the primary current is different for each position. When the handle is in a vertical position the circuit is broken, as there is no longer any contact between the vertical springs and the brass contact pieces. In front of the hammer-break six terminals are mounted in pairs. The two nearest the commutator, marked AA, are connected to the manipulating key, whilst the other two pairs, marked BB and CC, are fitted with two copper pins. The terminals B and C are connected internally to a condenser, K.

The Coil Condenser.—This condenser, which has a capacity of approximately 2 microfarads, consists of alternate layers of tin-foil and varnished paper. Alter-

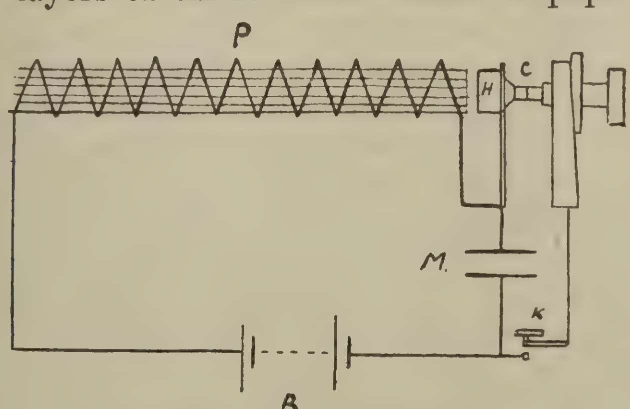
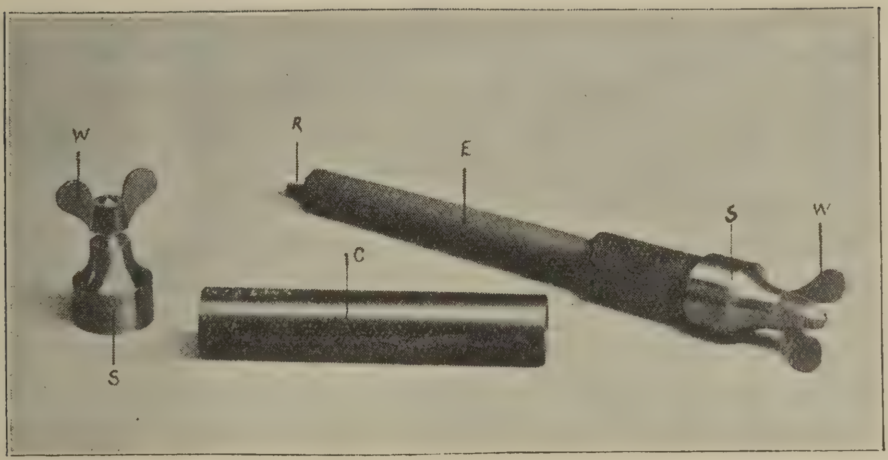


Fig. 135.—Induction Coil (Theoretical Sketch).

nate sheets of foil are connected at one end, the remaining sheets being all connected at the other end. Because the dielectric of varnished paper is very thin and the area of the conductors comparatively large, a fairly large capacity is contained in little space. In all there are 140 sheets of foil in the condenser. Fig. 135 shows the coil and condenser connections in a simple manner. When the key, K, is depressed, a current flows from the battery, B, through the primary winding, P, and the contacts, C, back through the key to the battery. The core of the coil is magnetised, and the hammer, H, is attracted. The circuit is thus suddenly broken at C. It has already been explained that any variation of the current in a circuit varies the number of linkages of lines of force and induces an E.M.F. tending to oppose the change of current. We see therefore that this breaking of the primary circuit produces a self-induced E.M.F. with a tendency to continue the current across the contacts.

This E.M.F. is of so high a value that a vivid spark takes place between the gradually-opening contacts, unless steps are taken to prevent it. This spark renders the air between the two contacts conductive, and the result is that the primary current continues to flow until the energy of inductance is dissipated. If the primary current is thus slowly cut off the induced effect in the secondary is only slight, as the rate of cutting of lines of force is slow. The importance of the condenser M is now seen. Immediately the contacts begin to separate, the induced E.M.F., instead of sparking across, is taken up to charge the condenser, the primary current being thus interrupted extremely quickly. Two beneficial results ensue. The spark being eliminated, no burning away of the platinum contacts takes place; and because the primary circuit is broken very quickly a much greater E.M.F. is set up in the secondary. It will be seen, moreover, that the charged condenser M is still in a closed circuit through the battery B and the primary winding, but that its E.M.F. is in the opposite direction to that of the battery. It begins to discharge itself through this circuit, this also tending to increase the effect in the secondary. When the primary circuit is broken the core loses its magnetism and the hammer is released,



PARTITION INSULATOR.

C. Ebonite collar.—E. Ebonite tube.—R. Steel rod.—S. Brass terminal socket.—W. Brass wing nut.

contact being once more effected at S. If contact is made before the condenser is discharged the primary current would at first have to overcome this back E.M.F., and as a consequence the rise of current—obstructed at the same time by the self-induction of the primary winding—is comparatively slow, and the induced E.M.F. in the secondary is of a correspondingly low value.

To summarise, the condenser helps to eliminate sparking at the contacts, helps to accelerate the "break" of the primary circuit, and helps to retard the current at the "make."

The result is that a much greater induced E.M.F. is produced at break than at make, and as a matter of fact if the spark gap in the secondary circuit be fairly large an intermittent unidirectional spark takes place. It will be seen that the condenser in the circuit shown also helps to eliminate sparking at the manipulating key contacts. It is generally found in practice that the coil works better with an extra condenser across the break, and terminals are mounted on the hammer spring base and on the back contact supporting pillar for making connection to an extra condenser, which is of the same type and dimensions as that contained in the base of the coil.

By means of the copper pins the coil base condenser may be easily cut out of circuit in the event of its breaking down.

Connections of Emergency Set.—Fig. 132 shows the complete connections between the various parts of the emergency set. P_1 and P_2 are two wooden pillars, each fitted with a brass plug socket. P_1 is permanently connected to the top plate of the earth arrester and P_2 to one of the coil discharge rods. The other coil discharge rod is connected to the bottom plate of the arrester. A piece of 20 ampère flexible cable, fitted with a boxwood and brass plug at one end and a brass thimble at the other, is used to make connection between the lower end of the aerial to either of these plug sockets. For transmitting the plug is placed in socket P_2, when it is seen that the aerial is connected to one discharge rod, the other rod being connected to earth. The choke-coils between the discharge rods and the ends of the coil secondary winding prevent any oscillatory currents

from the aerial-earth system rushing into the coil and damaging it. When the plug is placed in socket P_1 the aerial is disconnected from the coil and connected

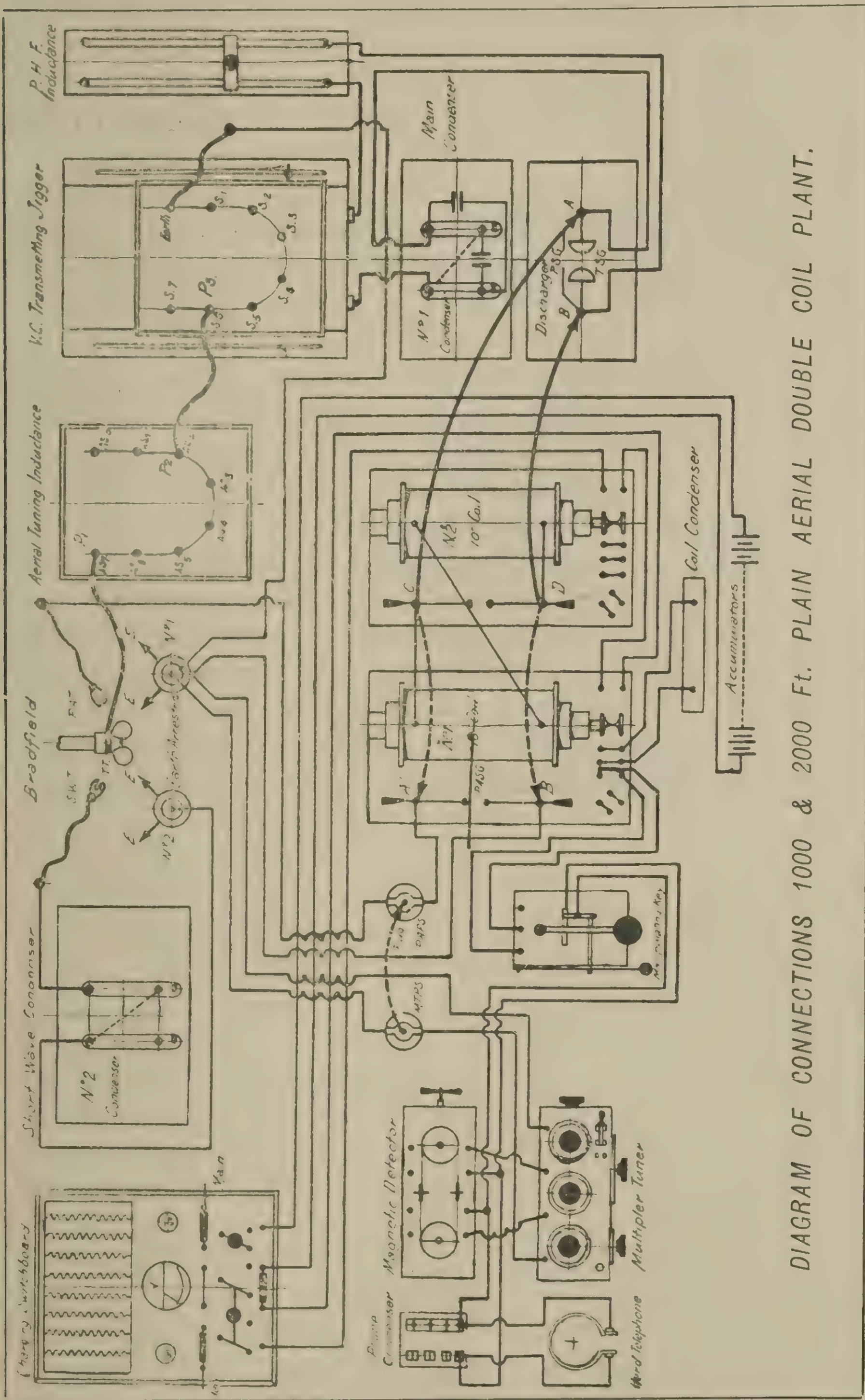


Fig. 136.— Connections of Double Coil Set.

to the receiving circuit joined across the earth arrester. If the coil were not disconnected from the aerial a direct path to earth for the received currents would exist through the secondary winding, not so much by way of the wire of the winding (which has too great an inductance to afford a path to signals of ordinary wave-length) as by a capacity effect from layer to layer and thence to the primary winding.

When using the emergency set the connection from the aerial tuning inductance to the lower end of the aerial is, of course, removed and replaced by the flexible connection mentioned above.

The Double Coil Set.—Some vessels are fitted with a transmitting set similar in detail to that of the $1\frac{1}{2}$ K.W. type, differing only in the fact that two 10-inch coils and direct current are used instead of the converter and transformer. That is to say, the closed and open oscillating circuits are the same as in the $1\frac{1}{2}$ K.W. set. In such cases the primary windings of the two coils are connected in series, and one of the breaks is screwed hard home, the condenser in this coil being disconnected. The secondaries of the coils are connected in parallel or series, as in the case of the transformer for the production of the long or short wave. The connections of such a set will be readily understood by referring to Fig. 136.

CHAPTER II.

THE AERIAL.

Aerials—T aerial—Inverted L aerial—Method of measuring—Spreader—Strain insulators, ebonite rod—Strop insulators—"Bradfield" leading-in insulator—Aerial trunks—Soldering—Tuning transmitting circuits—Wavemeter.

SHIPS' aerials are of two kinds, being either in the shape of the letter T or in the shape of an inverted L. The former type is preferred for the equality of range all round attained by its use, while the latter is preferred for its greater adaptability in erection. The size of the aerial is limited by such considerations as the height and distance separating the ship's masts, and the type of aerial is chosen in accordance with its adaptability to the position of the operating cabin, ship's funnel, stays, etc. On the great majority of ships the whole distance between the masts may be utilised for the aerial because the natural wave length of such an aerial is still less than that of the longer wave used in agreement with the regulations of an international convention. For the production of the short wave the aerials must almost invariably have their capacities decreased by means of a condenser in series, and this lessens the radiative power of the apparatus. The longer wave is the one most often used, whilst the shorter one is merely installed to conform with the regulations. As already stated, the natural wave length of the aerial is approximately between four and five times its length, so that, in cases where the length of aerial is considerably less than 200 feet, the addition of a condenser in series for the short wave is unnecessary. In the case of the White Star liner *Olympic* the distance between the two masts is so great that a certain amount of rope has to be used at the ends of the horizontal span, otherwise a series condenser would be necessary even when working on the long wave.

Where the masts are high and the funnel low, and the Marconi house is situated forward of the funnel, a T aerial may be advantageously fitted, but under any other circumstances the inverted L aerial is generally found to be more convenient.

If the T-shaped aerial is used, it is found that no difficulty is experienced with respect to the horizontal setting of the spreaders to which the ends of the aerial are attached, but if an L aerial be used there is a tendency for the spreader at the free end to swing into a vertical position, which, apart from its unsightly appearance, introduces the risk of becoming entangled with flags, etc. In the latter case it is necessary to use steadying guys, and as a consequence insulators must be inserted between the ends of the aerial and the spreader. If the T aerial be used full advantage may be taken of the

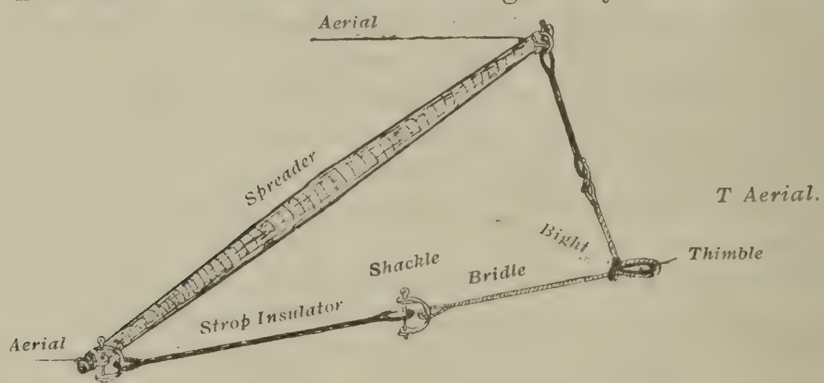


Fig. 137.—Spreader and Bridle (T Aerial).

distance between the masts by connecting the wires to the spreader and inserting the insulators between the latter and the mast.

The Spreader consists of an ash pole thicker in the

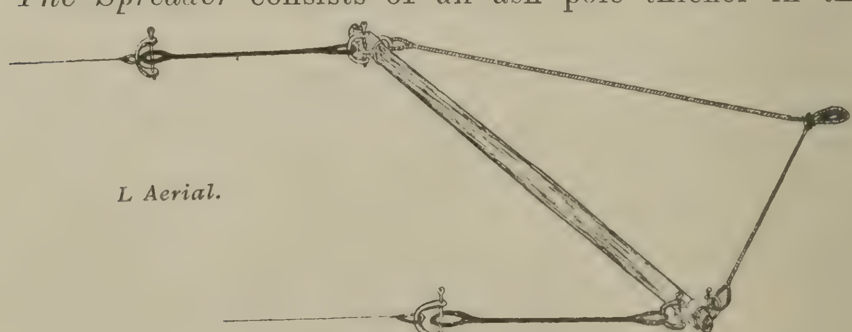


Fig. 138.—Spreader and Bridle (L Aerial).

centre than at the ends, $12\frac{1}{2}$ or 15 feet in length, fitted at the ends with light cast-steel double-lugged bands. A bridle of $2\frac{1}{2}$-inch tarred hemp rope fitted at the ends with a thimble is connected either direct to the lugs of the spreader-bands or else to the ends of strop insulators, the other ends of which are attached to the spreader. The bight of the bridle is fitted with a thimble, and the length of rope is such that the distance between the bight and the spreader is not more than 6 feet or less than 3 feet. Figs. 137 and 138 show the arrangement of the spreader and bridle for a T- and L-shaped aerial respectively.

Strain Insulators.—The aerial must be thoroughly insulated from the ship. For this purpose three principal forms of insulators are used. Strop insulators are used to insulate the ends of the aerial at the points of suspension. Strain ebonite rod insulators are used to insulate any aerial guys that may be used, and a special form of insulator is used for leading the lower end of the aerial into the operating room.

The strop insulators are made of cord covered with rubber and vulcanised, and are fitted with a thimble at either end. Those used with the $1\frac{1}{2}$ K.W. set are 3 feet in length. An occasional coating of bitumastic solution is found useful as a protection against rain. Complete and full instructions regarding these insulators are generally sent out with them. Fig. 138 shows the appearance of this type of insulator.

The strain rod ebonite insulators are supplied in pairs. Each rod has a ring screwed into each end, the rod being seized with wire to prevent splitting. One rod in each pair is fitted with a metal cone, as shown in Fig. 139.

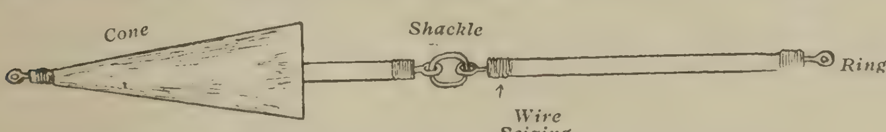
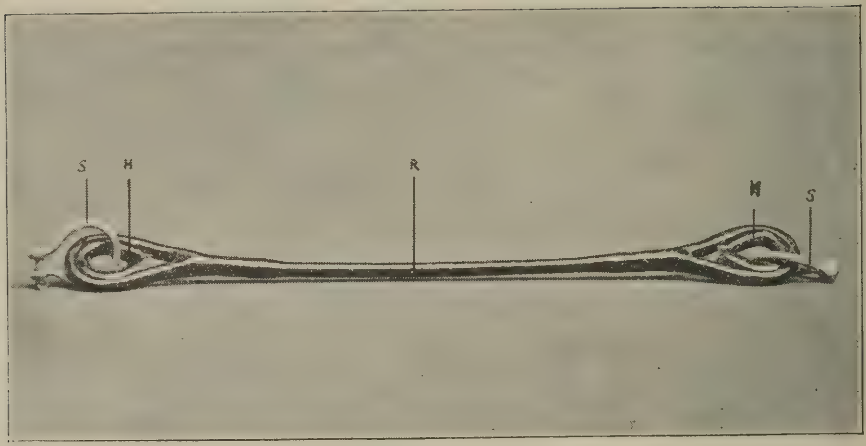


Fig. 139.—Ebonite Rod Insulator (Coned and Shackled).

The down leads of the aerial are usually held in the required position by means of stays, a pair of rod insulators being inserted between the aerial and the rope in such a manner that the apex of the cone is pointing upwards, the cone thus serving to protect the insulator, through a certain part of its length at least, from rain.



STROP INSULATOR.

R. Insulator proper.—S. Galvanised iron shackle.—H. Heart thimble.

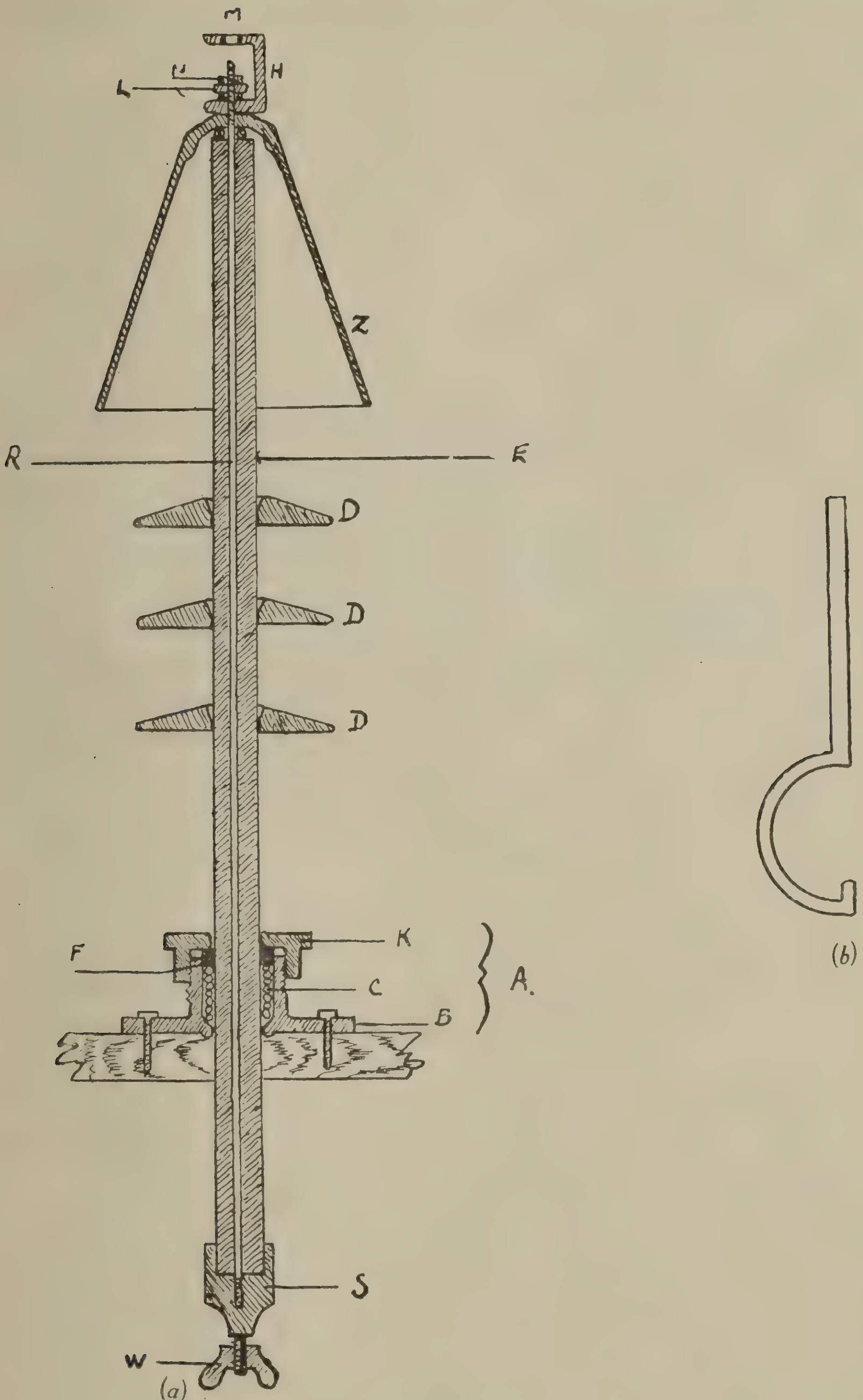


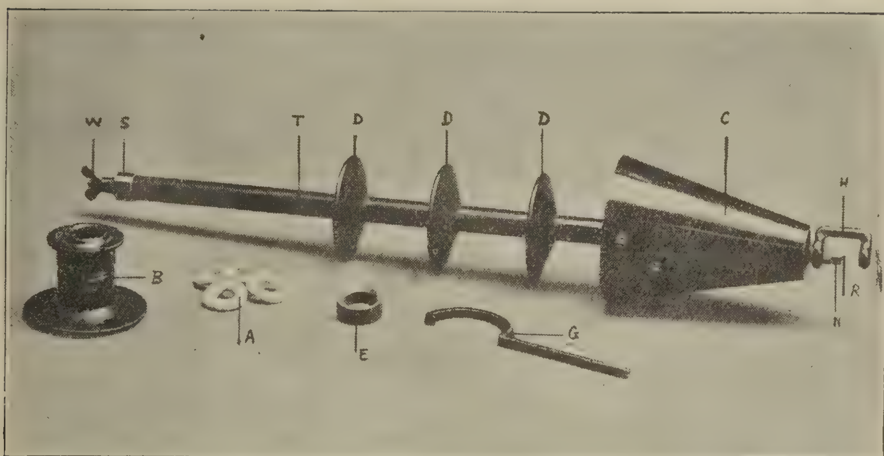
Fig. 140 (a) and (b).—“Bradfield” Leading-in Insulator and key.

The Leading-in Insulator.—This insulator, known as the "Bradfield" insulator, is shown in section in Fig. 140.

R is a $\frac{1}{2}$-inch steel rod which passes through a long ebonite tube, E, of $1\frac{3}{4}$ inches outside diameter. Each end of the rod is threaded, the lower end being fitted with a brass socket, S, supplied with a wing nut, W, and the upper end being supplied with a shackle head, H, a double terminal brass lug, L, and lock nuts, N. A zinc cone, Z, is fitted over the steel rod and rests on the top of the ebonite tube, being held firmly in position by means of the lock nuts, the joint being rendered watertight by means of an asbestos washer. The cone keeps part of the insulator dry under almost any weather conditions. Three ebonite discs, D, known as anti-spark discs, are fitted at intervals along the tube, and assist in preventing sparking over the surface in wet weather. The insulator is led into the cabin through a stuffing box, A, which consists of the following parts:—B is a hollow casting through which the tube passes, the space between the inner face of the casting and the tube being occupied by seven asbestos packing rings, C. An ebonite ring, F, fits over these rings, pressure being brought to bear on it, for the purpose of packing the asbestos rings tight, by means of a flanged metal ring, K, which screws on to the outside of the casting B. K has four notches cut round its periphery, and the gland key, shown in Fig. 140b, is used to screw it hard home in order to fix the insulator in a rigid position through the roof or the side of the cabin, as the case may be. The casting, B, is firmly fixed by means of four coach screws.

The lower ends of the two aerial down leads are given a turn or two round the shackle head, H, after having been passed through the eye, M, and are made fast in the double brass lug, L, by means of two screws.

Aerial Trunks.—In cases where the operating room is below the top deck it is sometimes necessary to provide an "aerial trunk" to carry the aerial through the intervening decks. Fig. 141 shows such an arrangement. T is a wooden trunk which must not be less than 10 inches across, DD being two decks between which the trunk is fixed. A separate leading-in insulator with stuffing-box



"BRADFIELD" LEADING-IN INSULATOR.

A. Asbestos packing rings.—B. Stuffing box.—C. Rain cone.—D. Anti-spark discs (ebonite).—E. Ebonite ring for stuffing box.—G. Gland key. —H. Iron shackle.—N. Brass nuts.—R. Steel rod.—S. Brass terminal socket.—T. Ebonite tube.—W. Brass wing nut.

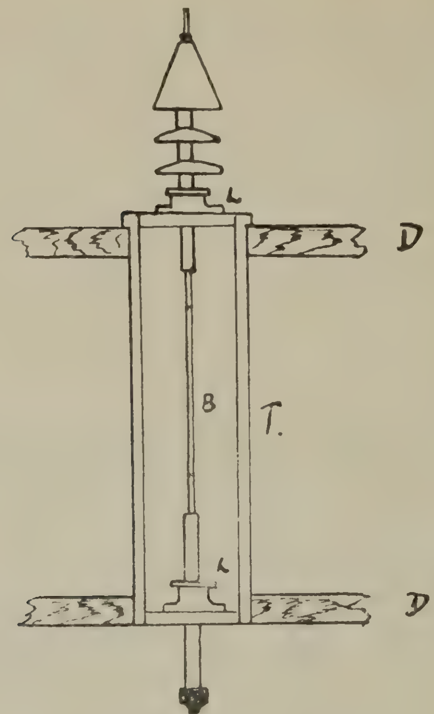


Fig. 141.—Aerial Trunk.

is fitted through each deck as shown at LL. The lower one, of course, does not need a protecting cone. A threaded metal tube, B, is used to connect the steel rods of the two insulators, this being preferred to cable, as there is no possibility of slack taking place and contact being made with the inside of the trunk. Doors are let in the side of the trunk in order that the insulators may be accessible for inspection. It is also occasionally found necessary to use such a trunk where the aerial has to be carried through an awning.

Fitting of Aerial.—Having decided which type of aerial is to be installed, it becomes necessary to obtain the exact measurement of the distance between the masts and the distance between the top of the Marconi cabin and the middle of the horizontal span if a T aerial is to be used, or the distance between the top of the Marconi house and the mast-head if an L aerial is to be used. These details may be obtained from the builders' rigging-plan or by actual measurement. The distance between the masts, less 5 per cent. for the stretching of the wire and

14 feet allowance for the space taken up by the bridles, should then be marked out on the deck. If an L aerial is to be used, a further 3 feet must be deducted to allow for the insulators at the free end. From the centre point of this marked distance, the distance between the top of the Marconi house and the centre of the horizontal span may be marked off in either direction for a T aerial. Then two lengths of wire are required equal to the length from either end to the centre point, and two lengths equal to the length from one end to the centre plus the distance from the centre to the point showing the distance from the horizontal lead to the Marconi house, for a T aerial. For an L aerial two lengths are required each equal to the total horizontal span plus the distance from the mast-head to the cabin.

For a T aerial the following illustration may be better understood :—

Fig. 142.—Measurements for T Aerial.

AB represents the distance between the masts less 5 per cent., and 14 feet. C is the centre point. CD represents the distance between the centre of the horizontal span and the top of the Marconi house. Then the following wires are required :—Two equal to AC and two equal to BD.

For an L aerial the following illustrates the method :—

Fig. 143.—Measurements for L Aerial.

AB represents the horizontal distance as before, less an additional 3 feet. AC represents the distance between the mast-head and the top of the Marconi house. Then the following wires are required :—Two equal to AB plus AC.

In making the measurement between the house and the horizontal span, in either case allowance must be made for any extra length required for the staying off of the aerial from parts of the rigging, etc. As the ends of the wires have to be seized round thimbles an allowance of, say, 6 inches, must also be made for each thimble. Fig.

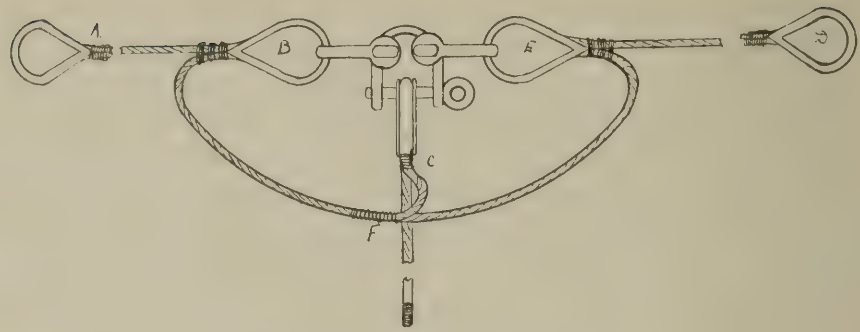


Fig. 144.—T Joint for Aerial.

144 shows how and where the thimbles should be fitted in the case of the T aerial. One end of the longer pieces is taken round a $1\frac{1}{2}$-in. heart thimble and seized with No. 20 soft copper wire, the seizing being afterwards soldered as shown at A. At the point B, about 4 inches from the point corresponding to C in Fig. 142, another heart thimble is seized, a third one being fixed at the point C in Fig. 144. A similar thimble is seized at one end of one of the shorter lengths D, and another one about 4 inches from the other end, E. The remaining end, F, of the shorter length is seized and soldered to the longer length at F. The three thimbles, A, C and E, are connected together by means of three galvanised iron shackles. It is thus seen that all strain is taken off the joint. The free ends of the T aerial are shackled to the iron rings on the spreaders, the ends of the bridle being also shackled to these rings. Care must, of course, be taken that the wires are taken outside all rigging before being connected to the spreader. Halyards are passed through the shackle at the bight of the bridle and pass through blocks at the mast-head. When all the connections have been made the aerial may be hauled aloft, and if the operations have been carefully carried out it will be seen that the two parts are symmetrically disposed. Ebonite strain rod insulators attached to guy ropes may then be connected to suitable points on the down leads, and the lower ends of the guys made fast to some part of the deck in such a manner that the down leads are kept clear of any obstruction.

Whenever a length of the aerial is running parallel to steel guys care should be taken that the latter are insulated

from the ironwork of the ship, otherwise considerable losses will ensue on account of induction.

After the aerial has been hauled aloft and the down leads stayed, the loose ends of the latter may be cut to the final required length and connected to the brass double lug of the leading-in insulator. The wire between the points at which the insulated guys are attached and the Bradfield insulator should hang slack—but in such a manner that there is no risk of it making contact with any part of the ship in swinging—in order that no strain may be put on the insulator itself.

Soldering.—When soldering the joints and seizing, it must be remembered that the solder will not hold unless the wire is clean. If the wire be cleaned with emery cloth, and if plenty of soldering paste be used, no difficulty will be found in making a good electrical joint. Of equal importance is the fact that heating weakens the aerial wire, so that in soldering the seizings care must be taken to use as little heat as possible and to avoid as much as possible heating the aerial wire itself in places where it will have to bear a strain.

Tuning the Transmitting Circuits.—For this purpose, unless the multiple tuner and detector be used in the manner described, a wave meter is necessary.

The Wave Meter.—A very convenient form of portable wave meter is made and used by the Marconi Company. It consists of a variable condenser in series with an inductance coil, which is usually made in two sections to give a wider range of usefulness. The inductance coil is contained in the lid of a teak box, and the two portions

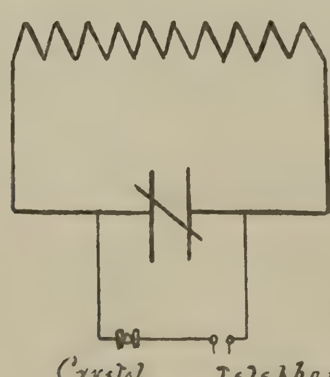


Fig. 145.—Wave-Meter, Marconi.

WAVE-METER.

B. Box containing spare crystals.—C. Carborundum crystal.—I. Inductance coil.—P. Telephone plug socket.—T. Telephone head gear.

are respectively connected in the circuit by means of a brass plug and sockets. Joined across the condenser are a telephone and carborundum crystal in series, the latter being held in position between two brass upright springs. The instrument is carefully calibrated and a card is supplied giving the wave lengths corresponding to the condenser readings when used with either of the two inductance coils. Fig. 145 shows the connections of the parts of this instrument. Wearing the telephones, the person making the measurement walks a little distance from the circuit in which oscillations are being produced and adjusts the condenser until the maximum strength of signals is obtained. The most accurate adjustment is obtained when the distance between the observer and the circuit under measurement is sufficient to produce *just audible* signals, as then any slight deviation from the correct adjustment causes them to fail altogether.

The transmitting circuit is tuned as follows:—

Tuning Low Frequency Primary Circuit.—It has been stated that the L.F.I.C.I.* should be adjusted until readings of 25 ampères and 75 volts are registered on the meters of the A.C. switchboard. This is, however, only a rough indication, and is only possible when the D.C. is supplied at 100 or 110 volts pressure.

A better method of adjustment is to vary the L.F.I.C.I. until a maximum spark is obtained between the electrodes with the machine running at the desired speed.

It is found that after the value of L.F.I.C.I. for the maximum spark has been obtained, although a decrease of this value gives a greater ampèrage, the length of the maximum spark obtainable is decreased.

Again, it is found that if too little inductance be included in the circuit the machine slows down considerably, and, vice versa, if too much inductance be included the machine speeds up on depressing the manipulating key.

The final adjustment of the L.F. Primary Circuit may be left until the oscillating circuits have been tuned, when the L.F.I.C.I. may be further regulated until the maximum glow of the tuning lamp is obtained.

* Low Frequency Iron Core Inductance.

Open and Closed Oscillating Circuits.

Long Wave.—The secondary of the transmitting jigger is run up clear of the primary. The converter is then started and the low frequency iron core inductance adjusted as described on a 600 meter main condenser adjustment—that is to say, with main condenser banks in parallel. The speed of the converter is adjusted by means of the field regulator until a steady spark is obtained during the transmission of a long dash. The variable high frequency sliding inductance is then adjusted until the reading on the wave meter shows that a 600 meter wave is being produced in the closed circuit. After seeing that all the choke in series with the tuning lamp is in circuit, the secondary of the jigger is lowered until it is just within the influence of the primary. With this very loose coupling, different values of aerial tuning inductance are tried until a reading on the wave meter held outside the cabin near the aerial or earth-lead indicates that a wave of the required length is being radiated. The tuning of the aerial may be checked by means of the tuning lamp. An adjustment of the choke is found which allows the lamp to glow just feebly. If an increase and decrease of one turn of inductance lessens the brightness of the glow in each case, the circuit may be considered as tuned. If the results obtained are not sufficiently well marked the coupling may be made a little closer. Finally, it is advisable to get into communication with some other station in order that the signals may be tested. A slight variation of the high frequency sliding inductance in the closed circuit may be found to be necessary to obtain the best results.

Short Wave.—The lower end of the aerial must be disconnected from the A.T.I. and be connected to one side of one bank of the extra condenser, the other side of the latter being connected to the upper plate of a separate earth arrester, as already described. The aerial must then be excited and the capacity of the condenser varied until the circuit is tuned for a 300 meter wave. The second bank of the condenser may then be built up to give the same wave-length when "buzzed" with the jigger-secondary and earth-lead as far as the earth arrester, and

the two banks connected in parallel. The A.T.I. may then be reconnected to the lower end of the aerial (at the Bradfield insulator) and its value adjusted until resonance is obtained as denoted by the tuning lamp.

When varying the capacity of each bank of the short wave condenser the zinc plates are gradually pulled apart until the value of the condenser is obtained for the required wave. Comparing the area of the opposing plates with the total possible area, and taking account of the distance separating the plates, it is possible to rebuild the bank so that all the glass plates may be used, thus maintaining the original rigidity of the arrangement. A number of the zincs must, of course, be removed, but as these are so very thin their removal does not materially affect the outside dimensions of the bank. As this "short-wave condenser" has to stand considerable voltages, the use of the full number of glass plates is desirable not only to preserve the rigidity of the whole, but also to provide sufficient dielectric strength. There should be at least three glass plates between each zinc.

If the aerial is of such a size that it is capable of being tuned for the transmission of a 300 meter wave, using only four turns of jigger secondary, without resort being made to the use of an extra condenser, this method is preferable to the one already described, as it facilitates changing over, and no loss, or at least very little, results from the cutting out of the three turns of jigger secondary, as the coupling—thus weakened—may be made closer again by sliding down the secondary of the jigger.

CHAPTER III.

The Five Kilowatt Set.

Essential differences—Double magnetic key—Iron core inductance —Transformer—Main condenser—Swiss commutator—High-frequency spiral inductance—Disc discharger—Valve receiver —Accumulators for—Charging board for accumulators.

The 5 K.W. Set.—The arrangements of the circuits in the different power sets is practically the same, the real differences only consisting of modifications in the various pieces of apparatus.

Starting with the transmitting gear and considering the circuits in the same order as was done in the case of the $1\frac{1}{2}$ set, the first modifications are found in the direct current circuit. Instead of using a rotary converter for the conversion of the ship's direct current into alternating current, a motor-generator is employed. This consists of a motor and an alternating current dynamo coupled together. A starter and field regulator are used in the motor circuit just as in the $1\frac{1}{2}$ set, the starter, how-

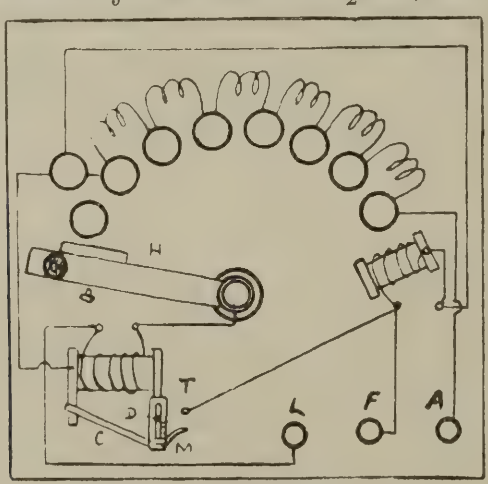
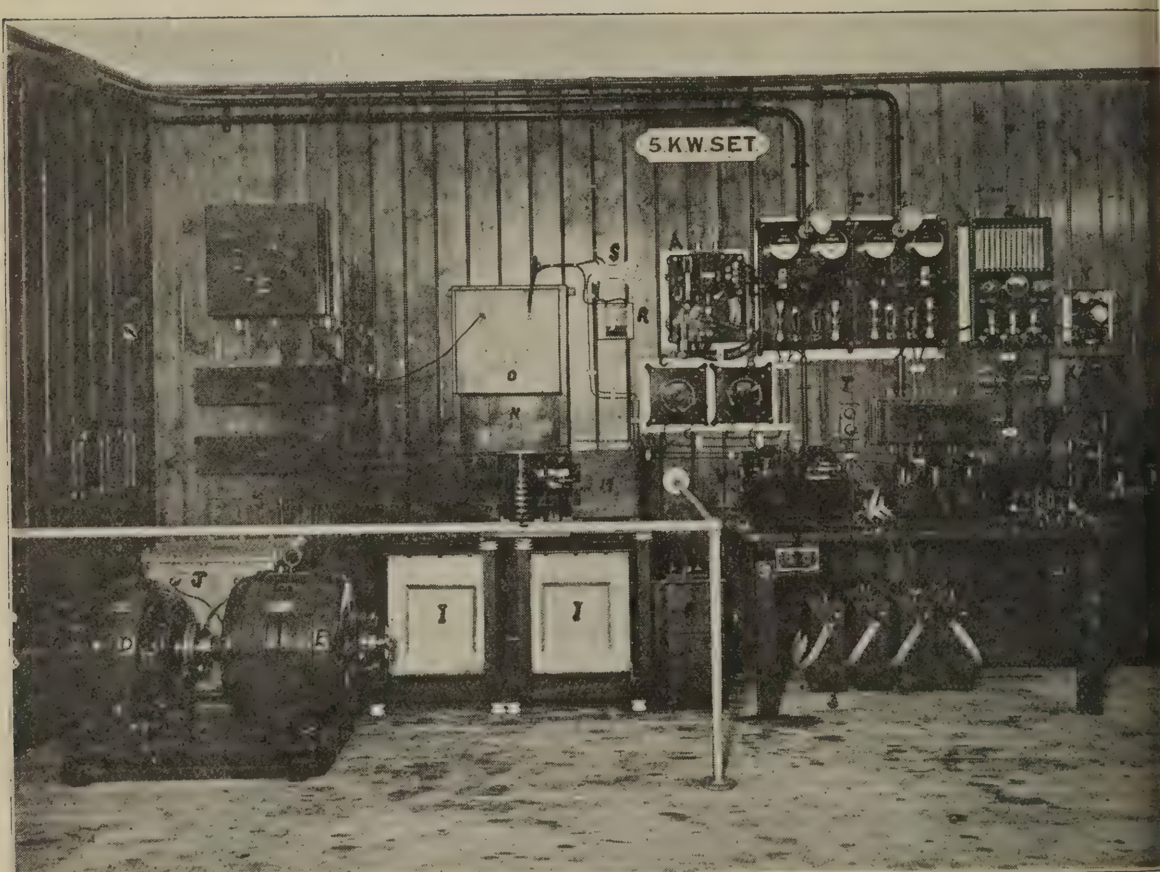


Fig. 146.—Starter 5 K.W. Set.

ever, having slightly different connections. Fig. 146 shows the starter, and it will be seen that an additional

electro-magnet is mounted on the slate face. This is an overload release of such design that when the current exceeds a certain amount the armature, C, is attracted upwards and makes contact with the stop, T, thus short-circuiting the no-volt release and allowing the starting handle, H, to fly back to a neutral position. The force necessary to attract the armature is greater if the latter be further away, and this affords a means of setting the overload release to any value between certain limits. The lower end of the armature is supported on a slotted brass strip which has its lower end bent at a right angle as shown at M. The position of this strip, which is marked with a scale of ampères, is adjusted with respect to the coil by means of the screw, D, so that any current exceeding the ampères shown on the scale is capable of causing the armature to be attracted. In this set the main switchboard has an extra panel which is supplied with voltmeter, ammeter, 100-ampère cartridge-fuses, pilot lamp, and knife switch, all these being used in connection with the direct current circuit. The generating part of the machine is slightly different from the type of dynamo previously described, in that the part which revolves is the *field*, and the stationary coils disposed round the inside of the framework are the ones in which the alternating current is *induced*. It will be seen, therefore, that the alternating current is not taken from slip rings as before, but from two fixed cables which are led out from the stationary windings. Now the strength of the induced alternating current depends on the intensity of the revolving field, and means are supplied for varying this intensity. The revolving field coils are therefore connected through a pair of slip rings mounted on the shaft, and through a variable regulating resistance, to the direct current supply. The regulating resistance is very similar to the field regulator of the motor in appearance, and its use is obvious. The complete connections between the mains and the main switchboard are shown in Fig. 147.

5 K.W. Machine Protecting Shunts.—Two guard lamps are used across the field and armature of the motor as in the case of the $1\frac{1}{2}$ set. In the case of the generating part of the motor-generator, protection is afforded by means of two graphite sticks, which are mounted on a



5 K.W. SHIP'S INSTALLATION AS FITTED IN THE LONDON SCHOOL.

A. Automatic Starter. (2) Switch for same.—B. Motor Field Regulator.—C. Alternator Field Regulator.—D. Motor.—E. Alternator.—F. Double Panel Switchboard, A.C. and D.C.—G Manipulating Keys.—H. Double Magnetic Key.—I. Full Plate Condenser Units.—J. Transforme —K. Air Core Choke Coils.—L. Spiral Inductance.—M. Discharger.—N. Jigger Primary.—O. Jigger Secondary.—P. Low Frequency Iron Core Inductance.—Q. Aerial Tuning Inductance.—R. Tuning Lamp.—S. Earth Arrester Spark Gaps.—T. Switch (Two-way)—U. Magnetic Detector.—V. Valve Detector.—W. Multiple Tuner.—X. Valve Accumulator Battery.—Y. Valve Accumulato Charging Board.—Z. Marine Type Switchboard.—3 Accumulator Battery.—4. Ten-inch Induction Coil.

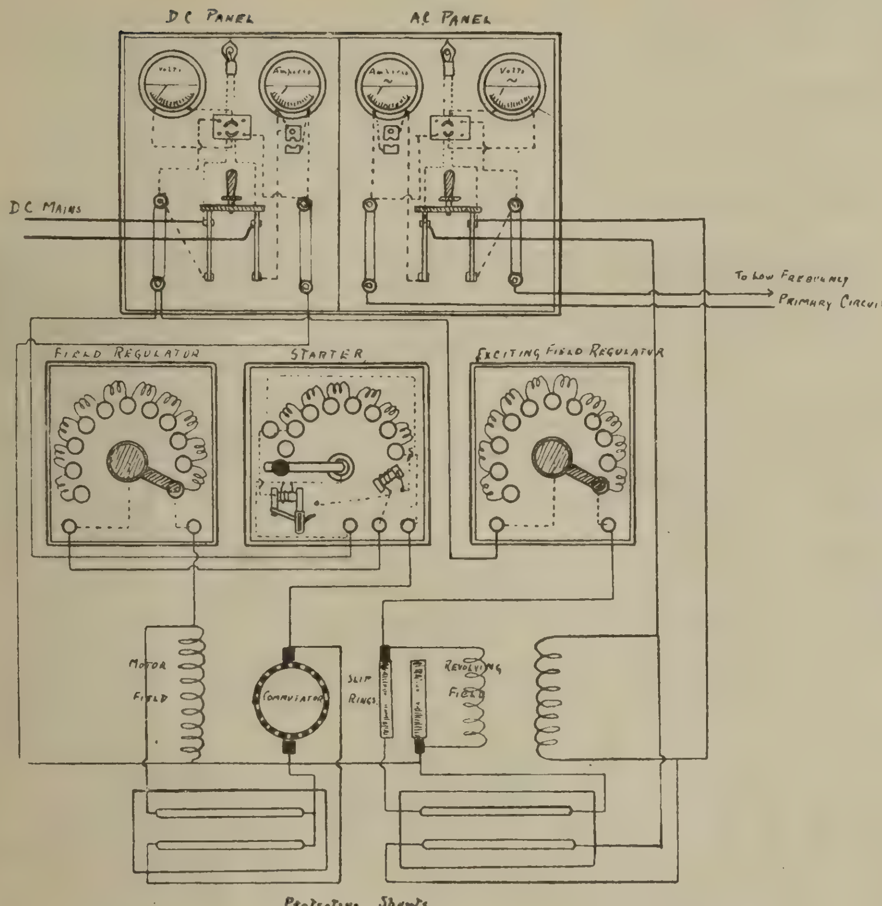


Fig. 147.—Motor-Generator Connections (5 K.W. Set).

base board carrying a spring clipping device instead of the flat springs used on the lamp board. This device is

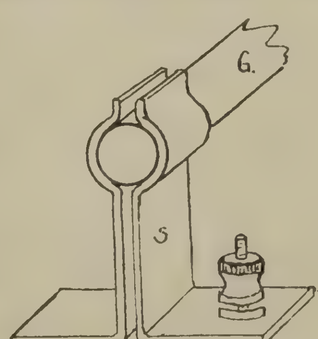


Fig. 148.—Standard for Graphite Stick.

shown in Fig. 148. G is the graphite stick fitting between the bent upper ends of the brass springs, S.

LOW FREQUENCY PRIMARY CIRCUIT.—The pieces of

apparatus in this circuit differing from the $1\frac{1}{2}$ set are the iron core inductance, the magnetic key, and the transformer.

The Iron Core Inductance is only different in that it is of greater inductive range and that the adjustment is made by means of an insulated brass handle moving over a series of brass stops.

The Magnetic Key.—The primary alternating current delivered from the motor-generator is at a pressure of anything between 100 and 300 volts, and a shock from such a source would be very unpleasant to an operator. Provision is made in a double magnetic key for obtaining on a low voltage from the manipulating key. A direct current of lower voltage is passed through the latter and through one pair of coils in the former, thus actuating an armature which closes the alternating-current low-frequency primary circuit. Fig. 149 shows the connec-

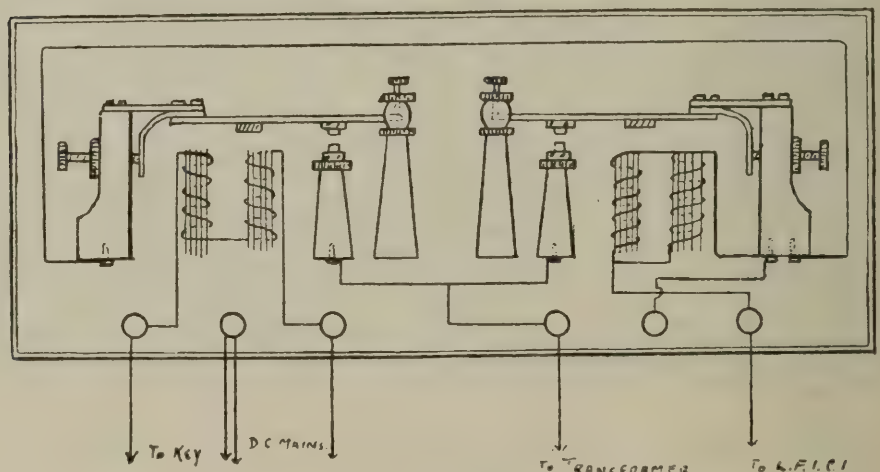


Fig. 149.—Double Magnetic Key (5 K.W. Set).

tions of the double magnetic key and necessitates no further explanation. The windings of the D.C. coils are of much finer wire and a greater number of turns than those of the A.C. coils, as the current used is so much smaller.

The Transformer.—This consists of an iron-core transformer with a continuous primary winding and a secondary divided into two parts. It is contained in an oil-tight galvanised steel tank which is filled with high-flash

insulating oil. The two ends of the primary are brought through heavy ebonite bushes to one side of the container, the four ends of the divided secondary being similarly brought to the opposite side. The secondary terminals are fitted with two brass straps, by means of which the two parts may readily be connected either in series or parallel. Fig. 150 shows how these connections

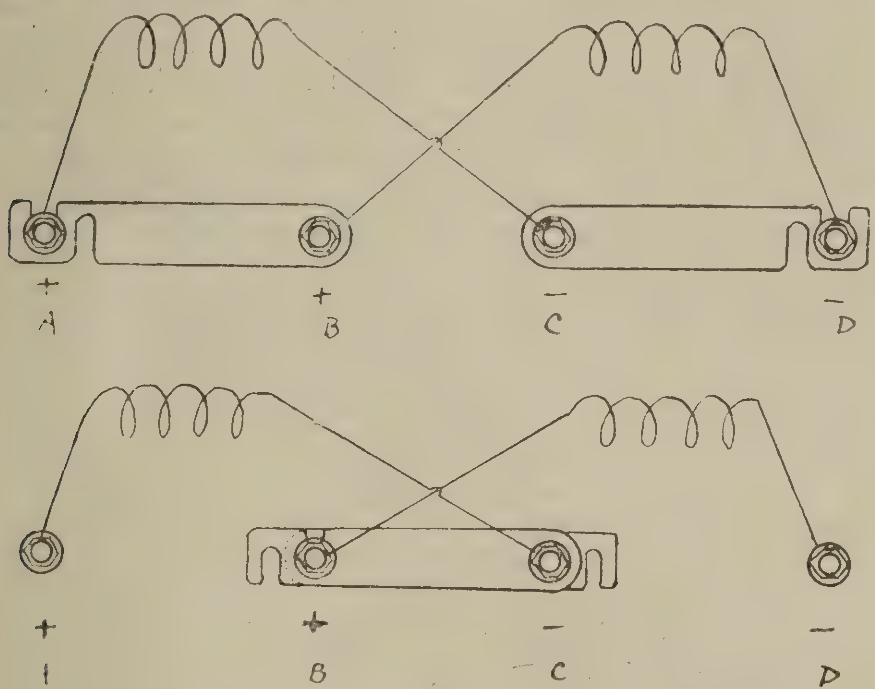


Fig. 150.—5 K.W. Transformer Connections.

are made. The two brass straps are connected between B and C for the series arrangement and between A—B and C—D for parallel. The transformer is capable of delivering 5 kilo-volt-amperes at either 10,000 or 20,000 volts when supplied with alternating current at 300 volts and 70 cycles. Such an output is capable of supplying sufficient charging energy to the condenser arrangement for wave lengths between 300 and 1,200 metres.

THE HIGH TENSION CIRCUIT.—The main difference between the 5 K.W. circuit and the $1\frac{1}{2}$ K.W. circuit is that the choke coils are much larger. The condenser will be considered in the closed oscillating circuit.

THE CLOSED OSCILLATING CIRCUIT.

The Main Condenser.—This condenser is capable of a

much wider variation of capacity than that used in the smaller power sets. Each bank is contained in a separate galvanised iron tank, which is filled with high-flash insulating oil, and the plates have twice the area of those previously described; the condenser consequently being known as a full plate condenser. In installations where the maximum wave length is 600 metres, four of these condensers are disposed on an insulated teak stand, and in cases where a wave of 1,200 metres is desired eight condensers are necessary. A wooden framework is erected round the condenser battery in such a manner that a controlling device may be placed immediately above the condensers, by means of which different parallel or series or series-parallel arrangements of the separate units may easily be effected.

The Swiss Commutator.—The controlling device is called a Swiss commutator and is shown in Fig. 151. A

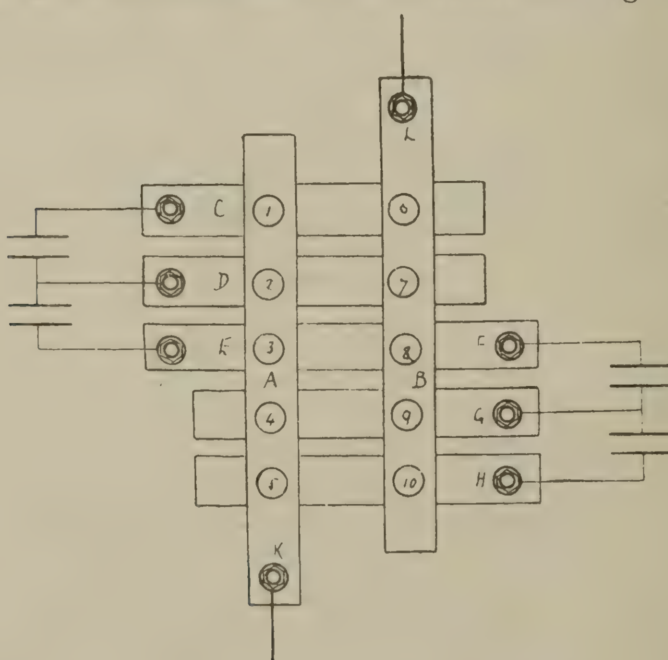


Fig. 151.—Swiss Commutator for 4 Condensers.

and B are brass tubes of square cross-section, each having five holes drilled through it. They are supported in a horizontal position on two ebonite standards, fixed on a baseboard which carries five tubes of similar cross-section, placed horizontally with their axes at right angles to A

and B and about two inches below them. The lower bars have terminal screws at the points marked C, D, E, F, G, H, and it will be seen that the centre tube has terminals at each end. The four condensers are connected to these terminals as shown. The terminals L and K of the upper tubes are connected to the leads from the air core chokes and also to the rest of the closed oscillating circuit. Brass plugs of the shape shown in Fig. 151a are used to

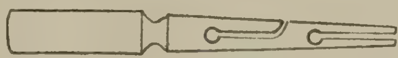


Fig. 151(*a*) —Plug for S.C.

connect the upper and lower tubes of the Swiss commutator. If two of these plugs be fitted through the holes marked 1 and 10 into corresponding holes in the tubes beneath, it is seen that the four condensers are joined in series. If plugs be placed through the holes marked 1, 7, 3, 9, and 5, or through the holes marked 6, 2, 8, 4 and 10, the four condensers will be connected in parallel. If plugs be placed through the holes marked 6, 3, and 10, the condensers will be arranged in two series of two in each series, the two series arrangements being connected to the circuit in parallel. Where a battery of eight units is used, the Swiss commutator consists of two halves each similar to the one just described, two brass connecting strips joining the inner and outer pairs of upper tubes, as in Fig. 152, the main terminals being placed one on

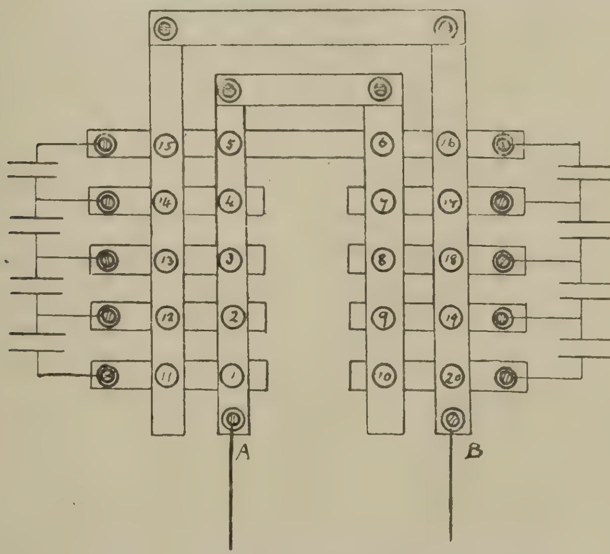


Fig. 152.—Swiss Commutator for 8 Condensers.

the inner and one on the outer tube at A and B. The lower tube C lies completely across the base as shown.

Using plugs through the holes marked 1 and 20, the eight condensers are placed in series, while the insertion of a third plug through the hole marked 15 and the transference of the plug in 20 to 10 gives a series parallel arrangement with four in each series. If plugs be placed through the holes marked, 1, 12, 3, 14, 5, 17, 8, 19, and 10, the eight condensers are in parallel.

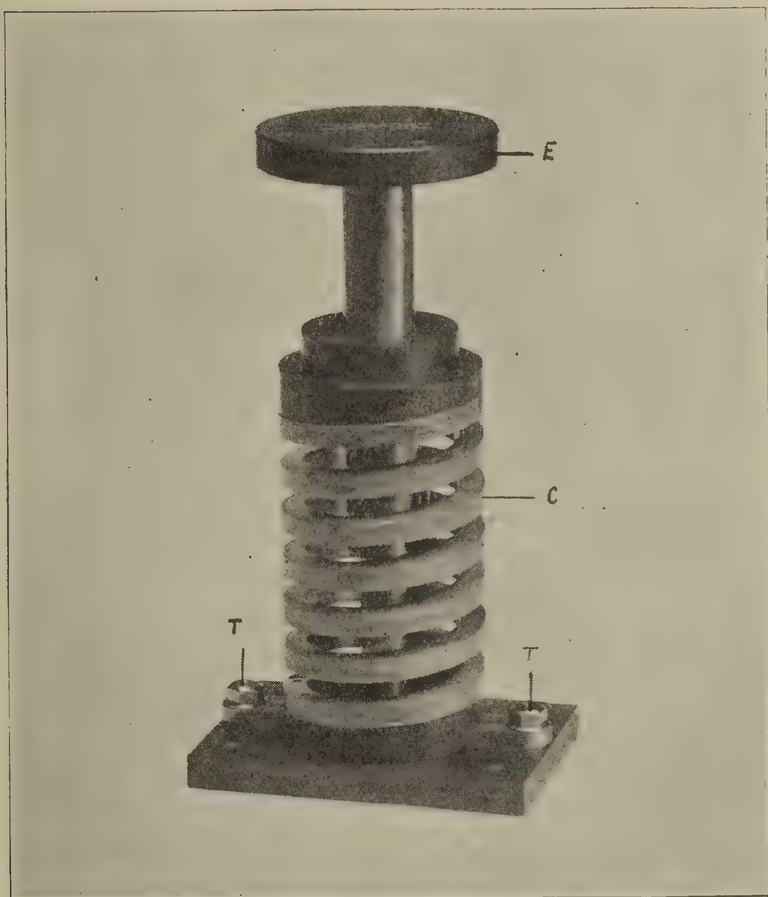
Finally, if plugs be placed through the holes marked 1, 13, 5, 18, and 20, four series arrangements are obtained with two units in each series, the four series being in parallel.

The connections between the condensers and the commutator are made with stout copper strip of ample surface, and ebonite strips are placed between the bars of the commutator and between the copper connecting strips to prevent sparking. Spark points of flat brass are fitted to the condenser terminals, and set so that any excessive voltage will break down the air resistance in preference to breaking down the condenser.

High-frequency Inductance.—A high-frequency inductance, consisting of a heavy copper spiral of square cross section, takes the place of the trombone or sliding inductance used in the lower-power set. A highly insulating ebonite handle, supplied with a flexible copper contact at the end of a brass screw of the same pitch as the spiral, is used to vary the amount of inductance in the circuit, thus enabling any adjustment of wave length to be made between those lengths given by the different condenser values. In some sets the same types of jigger and discharger are used as are used in the $1\frac{1}{2}$ set.

Where a 1,200-metre wave is required it is necessary to use a variable primary in the transmitting jigger in order to provide the necessary amount of inductance in the closed circuit. A jigger is provided, therefore, possessing four turns in the primary, the number used being varied at will by means of brass plugs similar to those used in the Swiss commutator.

The Disc Discharger.—A disc discharger usually replaces the fixed electrode discharger already described. It consists of a steel disc, about 10 inches in diameter,



HIGH FREQUENCY SPIRAL INDUCTANCE (5 K.W.)

C. Heavy copper spiral.—E. Ebonite adjusting handle.—
T. Terminals.

supplied with sixteen copper studs on either face near its periphery, which is rotated between two fixed copper electrodes. The disc is mounted on a continuation of the motor-generator shaft by means of an insulating rubber coupling, the disc and fixed electrodes being enclosed in a thick teak box so constructed as to deaden the sound of the discharge as much as possible. Heavily insulated ebonite handles project through two sides of the container, by means of which the distance between the fixed electrodes and the copper studs on the disc may be adjusted; and in order to allow for the movement of the stationary electrodes they are connected through heavy ebonite bushes to two external terminals by means of thick flexible cable. The external terminals are connected to the closed oscillatory circuit in the same way that the

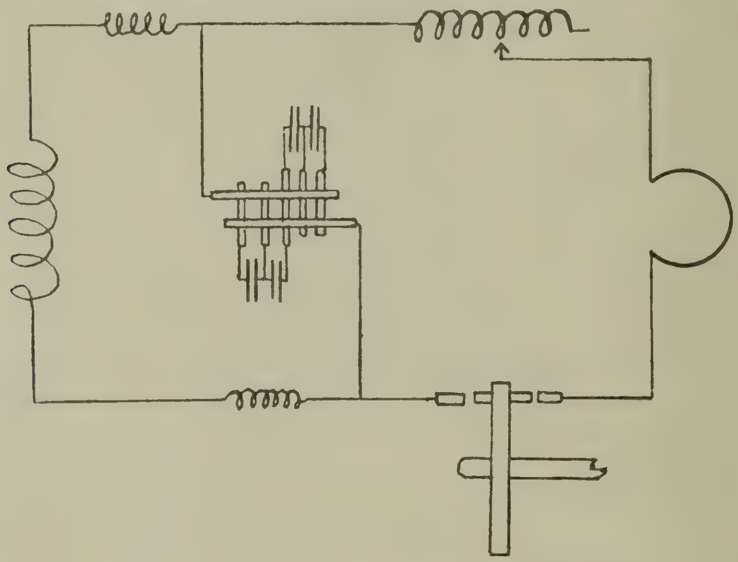


Fig. 153.—5 K.W. Closed Oscillating Circuit.

ordinary fixed discharger is connected. Fig. 153 shows the inclusion of a disc discharger in the closed circuit.

By means of this type of discharger the circuit may be adjusted so that the condenser spark discharge takes place at absolutely regular intervals, with the result that a very musical note is emitted. With the fixed discharger the note can only be a pure one if the voltage remains absolutely constant. If the voltage drops too low the spark will frequently miss, and if it rises too high an arcing spark is produced.

The disc discharger may be adjusted so that a spark takes place at each half period. If the voltage be a little lower at the end of one half-period than at the end of another, the spark takes place when the moving electrode has approached a little nearer the fixed ones, and *vice-versâ,* but on account of the speed of rotation and the small variation in distance required, the slight delay or advance of the discharge has little effect in spoiling the purity of the note.

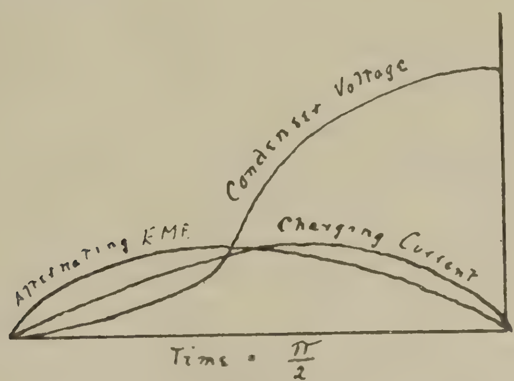


Fig. 154.—Condenser Charging Curves.

Fig. 154 shows the curves of alternating E.M.F., current and condenser voltage for one half-period, when the circuit has a natural frequency equal to that of the alternator (see paragraph on Resonance).

It is seen that the discharge takes place when the alternating current voltage is at zero value, this obviating any tendency to arc. Another advantage of this type of discharger is that the average length of the spark is rapidly decreasing as the disc electrode approaches the fixed electrode, this, of course, giving a decreasing spark resistance and less energy loss than in the case of the fixed discharger.

Because the spark must take place at a fixed time with respect to the voltage of the alternator, and as the relationship varies for different arrangements of condenser. a phase adjustment is provided. The rubber coupling between the machine and the discharger is fixed between two flanges on the ends of the two shafts. Quadrant slots are cut in the disc flange, which enable the disc to be fixed so that a moving stud is exactly between the fixed electrodes for different values of lag or lead. Bolts

through the quadrant-slots and a scale marked in phase degrees on the periphery of the disc-coupling flange enable any adjustment to be made easily and rapidly.

It must not be forgotten that the spark frequency has nothing to do with the oscillation frequency, the latter depending merely on the oscillation constant of the circuit, while the former depends on the speed of the disc and the number of studs employed. Thus, if the disc carrying sixteen studs rotates at a speed of 2,100 revolutions per minute, there will be 33,600 sparks per minute, or 560 per second.

THE OPEN OSCILLATING OR RADIATING CIRCUIT.—This is practically the same as for the $1\frac{1}{2}$ set. The jigger is usually supplied with adjusting rods, wheels, and screws, by means of which the coupling between the primary and secondary windings may be varied easily. Where a long wave is to be used one or more extra aerial tuning inductances are provided. The earth arrester, tuning lamp, etc., have already been described.

THE RECEIVING CIRCUIT.—A valve receiver is usually supplied with a 5 K.W. set in addition to the magnetic detector. A tuner somewhat similar in appearance to the multiple tuner is provided, with bayonet sockets for the accommodation of two carbon or tungsten filament lamps, and a switch enables either of the two to be placed in or out of circuit at will. The tuner contains the adjustable parts of three circuits—namely, the aerial tuning circuit, an intermediate circuit, and the valve circuit. The valve is never placed directly in the aerial circuit, as in the case of the magnetic detector, the only difference between the "stand-bi" position and the "tune" position being that the intermediate circuit is dispensed with in the first case. A theoretical diagram of the valve tuner when the change-over switch is on the "stand-bi" side is shown in Fig. 155. I_1 is a variable inductance in series with the aerial, the variable condenser C_1, and the inducing inductance I_2, the latter being connected to earth at E. AFR is the circuit suppiying current for the valve filament, A being a six-volt accumulator battery, F the filament, and R a variable resistance by means of which the glow of F is regulated. A resistance of fine wire is joined across the battery, as

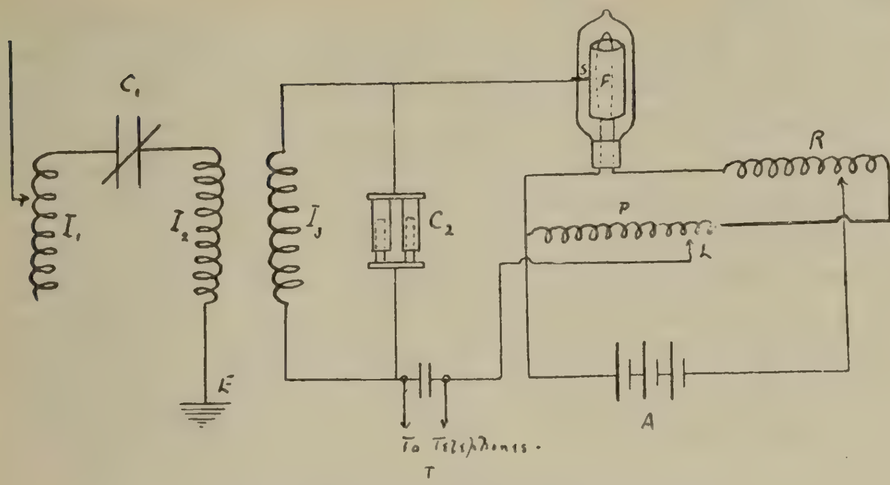


Fig. 155.—Valve Receiver (Theoretical).

shown at P, and is supplied with a sliding contact, L, forming a potentiometer by means of which the potential difference between F and the metal sheath, S, surrounding the filament may be varied. The valve circuit consists of the inductance, I_3 (the "jigger secondary"), the telephones, T, and the vacuum in the valve between the filament, F, and the sheath, S, together with a variable tuning condenser, C_2, of very small capacity. A condenser is also connected across the telephone. The variable condenser, C_2, is constructed on different lines from the aerial tuning condenser, which is of the disc type. Two brass tubes are made to slide over two ebonite tubes, inside which are two small brass rods. The brass tubes and rods form the conductors, and the ebonite is the dielectric.

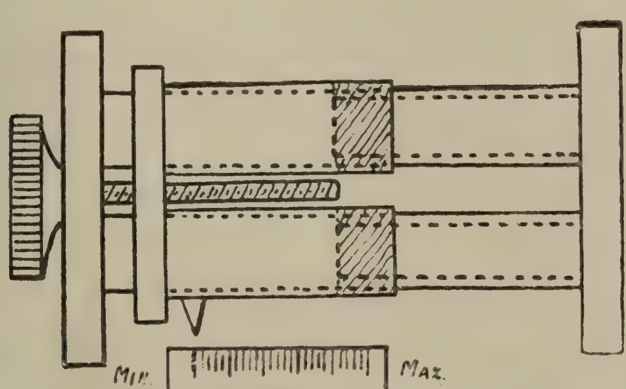


Fig. 156.—Double Billi Condenser.

the capacity depending on the area of the opposing surfaces. The adjustment is made by means of a screw carrying an ebonite knob at one end. As shown in Fig. 156, the movable tubes carry a pointer which indicates on a scale the value of the capacity in use. The active portions are shaded in the diagram.

The intermediate circuit is of the same type as the intermediate circuit of the multiple tuner, and is inserted between the aerial and valve circuits when on the tune side. The complete connections are shown in Fig. 157.

Two accumulator batteries are supplied with the tuner for supplying the necessary current. Each battery con-

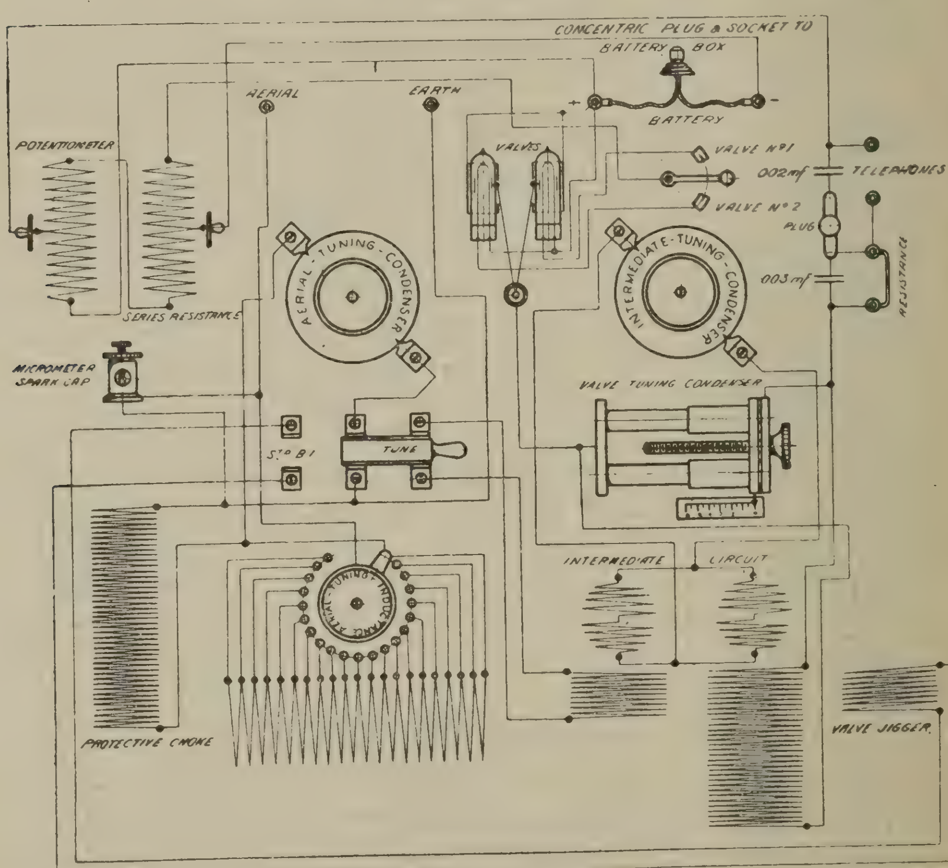


Fig. 157.—Valve Tuner Connections.

sists of three cells permanently connected together in celluloid containers. The accumulators are each contained in a polished teak box, fitted with a plug socket by

means of which connection may be made either to a charging switchboard or to the tuner. The batteries are of 40 ampère-hour capacity and require a normal charging current of 2·5 ampères, the specific gravity of the acid used being 1·190.

The Charging Board.—A small charging board is supplied to be used in connection with the valve accumulator-batteries. The two bayonet lamp sockets, L, a small moving-iron voltmeter, V, with a range of from 0—10 volts fitted with a small push button on its casing, two plug sockets, S, and terminals for two fuses, F, are mounted on a slate slab as shown in Fig. 158. The plug

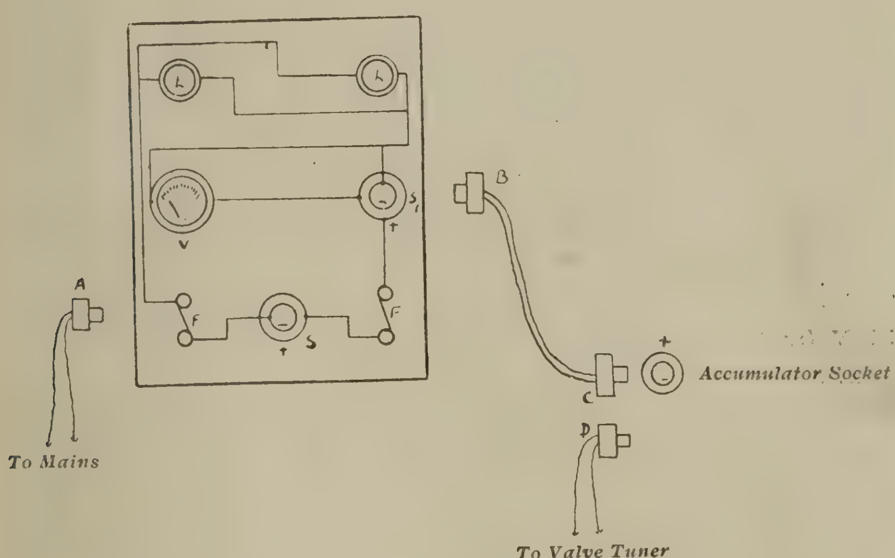


Fig. 158.—Valve Accumulator Charging-Board.

sockets consist of two concentric brass rings insulated from each other, and reference to the diagram will show that the centre ring is attached to the negative lead in both cases. Four plugs are supplied by means of which the various connections may be made. Two of these plugs are attached to the ends of a length of twin flexible wire, the inner contacts being connected to the ends of that part of the flexible which is covered with black braid. This ensures that when the two plugs are placed respectively in the socket on the accumulator box and the socket marked S_1 in the diagram, the negative plates of the

accumulators will be properly connected to the negative charging main, because the negative plates are connected to the inner ring of the socket on the box. A third plug is attached to one end of another piece of twin flexible wire, the other ends being connected to the positive and negative mains on the marine switchboard, care being taken that the black lead is connected to the inner ring of the plug and to the negative main. Two fifty-candle-power carbon-filament lamps are placed in the sockets to regulate the charging current to the required amount. It is seen that if the connections are made between A and S, B and S_1, and between C and the accumulator box, the accumulators will be on charge. A depression of the push button on the voltmeter gives a reading which indicates when the cells are charged. The fourth plug, D, is attached to one end of another piece of twin flexible wire, carrying two lugs at its other end which are connected to two terminals on the valve-tuner. When current is required for the valve it is only necessary to remove the charging plug C and to insert the plug D. Two separate accumulator-batteries are usually provided, so that while one is being used in connection with the valve the other may be placed on charge.

Note on Transmitter Connections.—In many diagrams of connections of transmitting sets, the leads from the transformer-secondary, after passing through the air-core chokes, are shown connected to the two sides of the condenser. This is a convenient way of drawing them, and is useful as reminding the reader that the condenser forms part of the low-frequency circuit as well as the oscillating circuit (hence the necessity of "tuning" the low-frequency circuit to the alternator frequency). But in actual practice it is found that if the leads in question are connected to the two sides of the *spark-gap* instead of to the *condenser*, there is much less strain on the insulation of the transformer under certain conditions. Hence, whenever possible these leads should be arranged to go to the spark-gap and not to the condenser.

½ K.W. SHIP'S INSTALLATION AS FITTED IN THE LONDON SCHOOL.

A. Main Switch.—B. Starter.—C. Field Regulator.—D. Rotary Converter.—E. Disc Discharger.—F. Low Frequency Inductance.—G. Main Condenser.—H. Manipulating Key.—J. Jigger Primary.—K. Jigger Secondary.—L. Short Wave Extra Condenser.—M. Aerial Tuning Inductance.—N. Tuning Lamp.—O. Earth Arrester Spark Gaps.—P. A.C. Switchboard.—Q. Magnetic Detector.—R. Simple Tuner.—S. Telephones.—T. Buzzer.
(The transformer and choke coils are hidden behind the converter in the cabinet.)

CHAPTER IV.

Small-power Sets.

$\frac{1}{2}$ k.w. set—Essential differences—Converter—Disc discharger—Closed core transformer—Air core chokes—Main condenser—Jigger—Simple tuner—Portable sets.

The $\frac{1}{2}$ K.W. Set.—A very efficient small-power set is very often fitted on cargo boats and small passenger liners. This set differs from the $1\frac{1}{2}$ and 5 K.W. in several constructional details, although the disposition of the pieces of apparatus and various circuits is very similar. The set has been designed to take up as little space as possible, and the greater part of the transmitting gear is contained in a small cabinet. As before, the various pieces of apparatus will be discussed in the order in which they appear in the circuits.

The D.C. Circuit.—This consists, as in the other cases, of a starter, field regulator, and converter. The starter and field regulator are of the iron-clad type. That is to say, an iron case fits over the face of each, the regulating handles being brought through a slot in the casing. The converter armature is designed to run on a vertical shaft instead of horizontally, the machine thus taking up less floor space. The upper extremity of the shaft carries an insulated steel disc fitted with eight copper electrodes, the disc being contained in a metal chamber, the top portion of which is an ebonite disc carrying two adjustable electrodes. The commutator and slip rings are mounted near each other between the armature and the rotary spark disc. Fan vanes are also attached to the shaft in such a position that cool air is sent into the disc chamber whilst working, thus preventing over-heating of the electrodes. The machine is wound with eight field-magnets, so that four cycles of alternating current are produced for each revolution. The normal speed is 2,250 revolutions per minute, so that a frequency of 150 cycles is obtained. As eight studs are employed on the disc the

spark frequency is 300 per second. When using a disc discharger, care must be taken that the moving and fixed electrodes are placed so that the space between them is as small as possible. Unless this care be taken, and unless the ebonite cover carrying the fixed electrodes be kept perfectly dry and clean, a spark will be found to jump across the face of the ebonite which will burn a groove in it and put the machine out of operation.

THE LOW-FREQUENCY CIRCUIT.—This circuit contains a small switchboard carrying a knife switch, fuse-ways, and ammeter, a manipulating key with short-circuiting contacts, an air-core low-frequency inductance, and the primary winding of a transformer. It is seen, therefore, that the magnetic key used in the other two sets has been dispensed with, this being on account of the lower current values dealt with.

The regulating inductance differs in that the coil is wound over a fibre instead of an iron core, and that it is supplied with six terminals arranged in a circle on one end instead of being arranged down the centre of one face of the container.

The cartridge fuses used are of 20 ampère capacity.

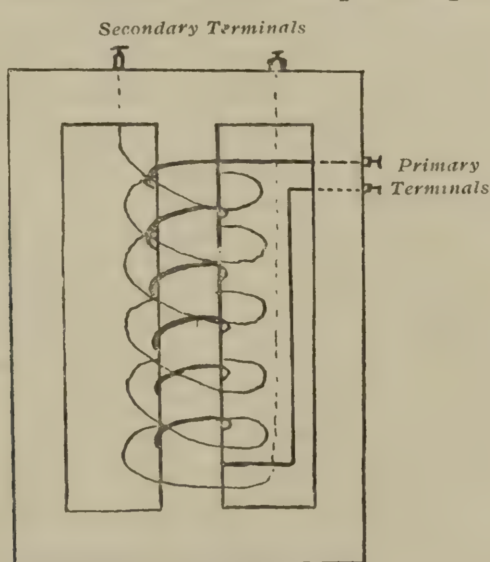


Fig. 159.—Closed Core Transformer ½ K W. Set.

The Transformer consists of primary and secondary windings over a closed iron core, as shown in Fig. 159. Unlike the 1½ and 5 K.W. transformers, only one arrange-

ment may be used, as the two windings are not divided. The coils are enclosed in ebonite casing, the whole being contained in a cast-iron frame. The transformer is air-cooled instead of being oil-cooled, as in the other cases.

The H.T. and the Closed Circuit.—This circuit contains the transformer secondary winding, the air-core chokes, the main condenser, and a variable inductance, the latter forming at the same time the primary of the jigger.

The Air-core Chokes consist of windings of enamelled wire over porcelain insulators, which are mounted by means of bolts on the framework of the transformer.

The Main Condenser is similar to one bank of the $1\frac{1}{2}$ K.W. condenser, except that a smaller number of zinc plates is used and that two glass plates separate each pair of zincs. It is seen, therefore, that the capacity of the main condenser is fixed, and not variable as in the other sets described. This is partly because the transformer does not allow of variation of the supply voltage and partly because the power available is not suitable for the charging of a condenser of larger capacity.

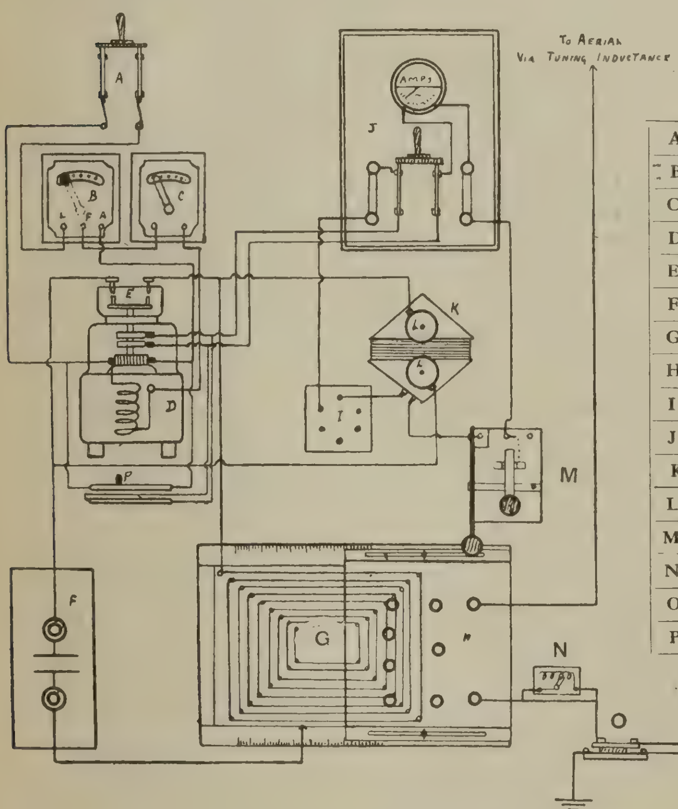
As the oscillation constant of this circuit cannot be varied by any alteration of the capacity, it is necessary to make the range through which the inductance is variable much greater than in the $1\frac{1}{2}$ and 5 K.W. sets.

The Jigger.—The jigger primary is therefore constructed of a number of turns of copper strip. The adjustments of the closed oscillating circuit for the 300 and 600 metre waves are made by varying the points at which the leads are clipped to the inductance. This inductance is carried on an insulated stand placed on the top of the cabinet containing the transformer, main condenser, converter, and low-frequency inductance, and the leads to it consist of heavy flexible cable brought through ebonite bushes in the top of the cabinet.

The Radiating Circuit.—The jigger secondary is similar to those already described, except that the windings are open to view instead of being boxed in. It slides over the primary in order to vary the coupling. The aerial tuning inductance is of similar construction, the windings being open to view.

The Receiving Circuit.—The only differences in the receiving circuit are that no telephone condenser is used

and that the tuner is of simplified construction and is known as a simple tuner. Instead of containing parts of three coupled circuits, the intermediate circuit is omitted and only two variable condensers appear on the top of the instrument. The tuning switch is also cut out, and the intensifier handle for altering the coupling is replaced by a small brass arm which moves over a brass quadrant mounted on the front of the tuner, in the place occupied by the tuning switch in the type already described. The variable inductance and change-over switches are similar to those of the multiple tuner. A complete drawing of the $\frac{1}{2}$ K.W. transmitting connections is shown in Fig. 160.



A	*Main Switch*
B	*Starter*
C	*Field Regulator*
D	*Rotary Converter*
E	*Rotary Discharger*
F	*Main Condenser*
G	*Jigger Primary*
H	*Jigger Secondary*
I	*Low Frequency Inductance*
J	*Switchboard*
K	*Transformer*
L	*H.F. Choke Coils*
M	*Key*
N	*Tuning Lamp*
O	*Earth Arrester*
P	*Guard Lamps*

Fig. 160.—Connections of Transmitting Gear $\frac{1}{2}$ K.W. Set.

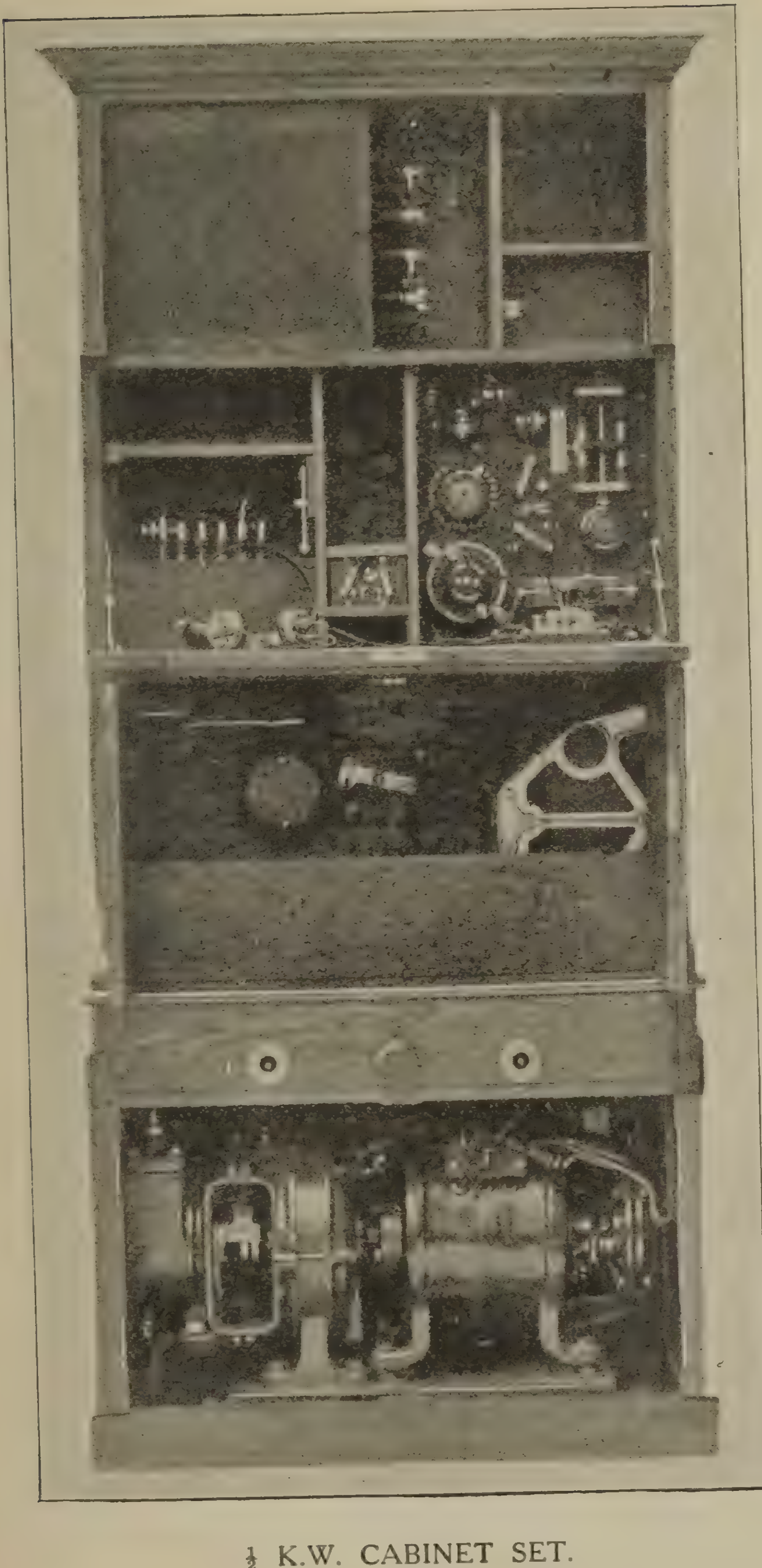
PORTABLE SETS.

In addition to the standard sets of apparatus already described, which are essentially designed for use on board ship, a series of portable sets is

manufactured by a special department of the Marconi Company. These sets range in power from the small knapsack set of about one twenty-fifth of a kilowatt to the motor-car set of three kilowatts. The first-mentioned set derives its power from either a small primary or secondary battery, but it is intended to introduce a hand-driven magneto machine for this purpose at an early date. The other sets, consisting of pack sets for transportation on horse or mule back, and the higher-power installations designed for transportation in field-carts, usually obtain their low frequency primary current from a small alternator directly coupled to a small petrol engine. In the motor-car outfits the engine may be used for propelling the car or for driving the alternator when the car is stationary.

In every case the apparatus is designed with due consideration to weight and bulk, although when a complete installation is set up the general disposition of the circuits is the same as already described in preceding chapters. The chief difference in the transmitting apparatus is found in the main condenser. In all the portable types the oil condenser is replaced by tube condensers. The latter consist of glass tubes coated inside and outside with copper. The copper is electrically deposited on the glass, a very efficient condenser being thus provided. A broken tube may be very quickly and easily replaced, this being of particular advantage in a set which is designed for use during military operations.

Most of the sets are arranged for the transmission of three different wave lengths, and a switch is used by means of which all the necessary alterations in the various circuits may be effected in a minimum space of time by one simple movement. The necessity of such an arrangement will be readily understood when it is remembered that the possibility of an enemy reading the messages must be reduced to a minimum. By continuously altering the wave length during transmission great difficulty would be experienced at a receiving station unless it were provided with a means of quickly making corresponding changes in the receiving circuits. A type of receiver known as the "Commutator Type" is used for this purpose. Three coupled circuits are included in this receiver



½ K.W. CABINET SET.

(as in the case of the multiple tuner), but of such dimensions that the movement of a single switch places each of the three circuits in tune for the reception of any one of the wave lengths transmitted by the corresponding station. A simpler form of receiver, known as the "Flexible" type receiver, is installed in some portable sets. This receiver contains two circuits similar to the circuits of the "Simple tuner" already described, and receives its name from the fact that the circuits are continuously adjustable for any wave length within the upper and lower limits.

It has been stated that the earth connection on board ship is obtained by means of a bolt screwed into the iron bulkhead. At a permanent land station the "earth" usually consists of a number of buried plates or a wire network buried in the earth underneath the aerial system. As the process of burying earth plates or wires takes a considerable space of time a different arrangement is adopted in connection with a portable station. This consists of the spreading of a copper gauze net which may be very easily placed in position and which serves excellently as an "earth."

The aerial is suspended from masts which are built up in sections, each section being fitted with a socket at one end and a plug at the other, all sections being interchangeable. Guy ropes are supplied with each mast.

The Cabinet Set.

The "Field Station Department" has recently designed a different type of portable set, which, in addition to being specially adapted to communicate with the various portable sets, is equally suitable for use on board ship, particularly where a special cabin cannot be set aside for wireless purposes only. Because of its compactness and appearance it is an ideal station for private yachts or installations in private houses. The set referred to is known as the "Cabinet set." The whole of the apparatus is contained in a small oak cabinet 70 inches high, 30 inches wide, and 16½ inches from back to front when closed.

The bottom section of the cabinet contains a small motor-generator capable of an output of ½ k.w. The motor

and generator parts are mounted on one bedplate and a rotary discharger is mounted on the end of the shaft, a small fan being also mounted on the shaft to expel the heated air from the cabinet when working.

The closed oscillatory transmitting circuit is contained in the section of the cabinet immediately above the motor-generator.

It consists of a closed iron-core air-cooled transformer, a glass-tube condenser battery, a variable inductance, and the primary of an oscillation transformer or jigger, together with a two-way switch for changing the wave length of the closed circuit.

The secondary of the jigger is mounted in the third section of the cabinet immediately above the transmitter, and may be adjusted by means of simple clamp connections to suit any aerial within reasonable limits. In the same section as the jigger secondary is found the receiving apparatus, consisting of two coupled circuits with suitable tuning condensers and inductances for each. The crystal receiver is supplied, but terminals are mounted to which any other form of detector may easily be connected.

The range of wave lengths for which the receiver may be used is from 300 to 1,000 metres. In a small partition between the receiver and the transmitter secondary a tuning buzzer is placed, by means of which the receiving apparatus may be tuned for the reception of any particular wave length.

The top section of the cabinet contains the aerial tuning inductance, a small compartment for accommodating the battery used in connection with the receiver potentiometer, and a small compartment for the storing of any spare material. On opening the section of the cabinet containing the receiving apparatus, it is found that the cover provides a desk and is fitted with a transmitting key provided with a spring arrangement by means of which the receiving circuit is disconnected when transmitting.

Immediately above the motor-generator section three key sockets are fixed for the exciter, starter, and field resistances respectively. A small brass key fitted with an ebonite insulating handle may be used for starting the

machine and for varying the field and alternator exciting resistances. Guard lamp boards are also fitted in the section occupied by the machine.

Two heavily bushed terminals pass through the top of the cabinet to which the aerial and earth connections are made.

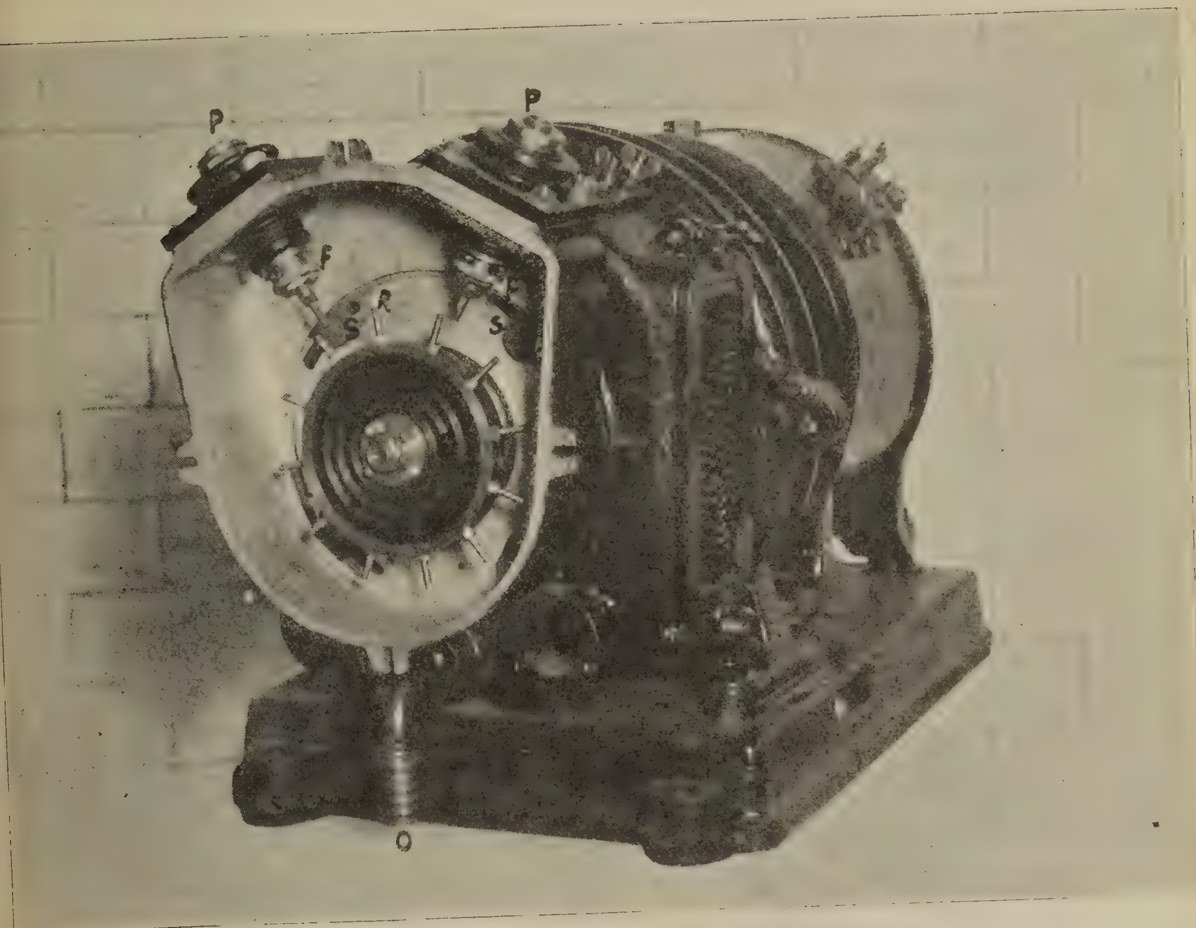
Adjustment of Disc Discharger.—The correct adjustment of the discharger is one of the most important points to be attended to in the whole of the transmitter, and the smooth working of the station depends largely on this.

An incorrect adjustment of the disc, amongst other things, will cause excessive strain on the transmitting condenser, excessive strain on all the insulation of the primary transmitting circuit, arcing at the manipulating key contacts, and a bad toned note.

The main condenser, especially when designed for use with a disc discharger, is supplied with safety spark points, which protect it from breakdown due to excessive voltage. The spark points should be set at a distance of about 8 millimetres.

The fixed electrodes of the discharger should be adjusted so that they nearly touch the ends of the disc studs, care being taken to turn the armature completely round by hand in order to make sure that the studs are of equal length and all clearing the fixed electrodes.

The machine may then be started and the manipulating key depressed, when a spark should take place between the fixed and moving studs. If this spark be of a ragged character, or if sparking takes place very freely at the safety spark-gap, the phase relationship between the fixed and moving electrodes should be slightly altered. This alteration is made in two different ways. In one type of machine the casing in which the stationary electrodes are fixed may be moved, whilst in another type (already described) the disc coupling may be adjusted. In either case, if the sparking be bad, the relative positions of the fixed and moving studs must be varied until a position is found in which sparking at the safety gap and key contacts is reduced to a minimum. In this position the spark will be found to possess a good tone which may be slightly raised or lowered by speeding up or slowing down the machine.



½ K.W. MOTOR GENERATOR WITH DISC DISCHARGER CABINET SET.

E. Ebonite Disc.—F. Fixed Electrodes.—P. Plug Sockets for High Frequency Leads.—R. Rotating Studs.—S. Slots with bolts for locking fixed electrodes inposition.

On looking at the rotating disc while the sparking is taking place, owing to an optical illusion, the disc appears to be standing still. When the position of the fixed electrodes is correct the disc apparently remains extremely steady, but if the position is not correct it appears to jump about in an erratic manner. When the correct phase position has been found, a maximum aerial current will be obtained (provided, of course, that the various circuits have been properly tuned), which, of course, will be indicated by the intensity of glow of the tuning lamp. This lamp therefore provides a good means of determining when the correct adjustment has been obtained.

CHAPTER V.

FAULTS.

Faults—Testing—Various circuits—Various instruments—The buzzer circuit—Sparking buzzer—Shunted buzzer—Improvised shunt for converting sparking buzzer to shunted type—Excitation by means of shunted buzzer—Different methods of excitin for tuning purposes—Improvised receiving circuit.

THE general design of the standard apparatus used in any of the low-power sets made by the Marconi Company is of such a nature as to render it almost "fool-proof." The dimensions of all parts are such that they can carry loads much heavier than those used in actual practice without fear of injury; and the insulation is of a most substantial character. Nevertheless, the nature of the service demanded from the apparatus is the occasional cause of a breakdown. The vibration of a ship in a heavy seaway may result at any time in minor breakages, such as the snapping of a wire or the working loose of a connection. Again, the way of electricity with a circuit may provide another of those things which are to be wondered at, but as a rule in a properly installed equipment very few occasions arise on which a fault may not easily be rectified. During an examination for the Postmaster-General's certificate of efficiency, however, the candidate is often faced with an installation in which a great number of superficial faults have been made in order to test his knowledge. Each circuit will therefore be once more discussed in the same order as before.

The Direct Current Circuit.—The converter must first be started. The main switch is therefore closed after making sure that the starter is "open," and the starting handle brought over on to the first stop. Perhaps the armature will not commence to rotate. Should the guard lamp across the armature glow, it indicates that the feeding and distributing mains are properly connected to the main switch, and that the fuses of the latter are intact.

The brushes may then be examined to see if they are making proper contact with the commutator. After the brushes have been properly adjusted a second attempt may be made to start the machine. If the armature still fails to rotate, a heavy arcing spark may be found to take place between the contact of the starting handle and the studs on allowing the former to come back to a neutral position. This indicates a disconnection in the field circuit and is due to the inductive effect set up by the sudden breaking of a circuit containing inductance (the armature coils).

The field circuit may be found to be interrupted at any of the following points:—

One or both ends of the no-volt release winding may have been disconnected from the terminals on the face of the starter. A break may have been made in the series resistance of the field regulator or the starter, or one of the leads between the various parts of the circuit may have been disconnected. The connection from one end of the field winding to the brush which is common to both field and armature circuits may have been disconnected. Any external disconnection may, of course, be easily found and remedied. A break in the resistances may be found by first disconnecting the starter and field regulator from all leads and by placing a galvanometer and dry cell in series between each pair of adjacent studs. A deflection of the galvo needle indicates that the connections are all right.

After successfully starting the armature it may be found that the starting handle will not be held up against the no-load release. This may be due to the following causes:—

The no-volt release winding may have been shorted with a small piece of wire. The armature of the over-load release may have been jammed hard up against the stop, thus shorting the no-volt release; or too much tension may have been put on the antagonistic spring contained in the barrel of the starting handle.

Primary Circuit.—After the converter has been started, a glance at the pilot lamp on the Iolanda switchboard will show whether alternating current is being delivered to the board. If the lamp does not glow, the alternating

current brushes on the slip-rings, the leads from the brushes to the lamp, and the lamp itself should be examined and any disconnection made good.

If the switch on the Iolanda board be now closed and the manipulating key depressed the armature of the magnetic key should vibrate. In the case of the failure of the magnetic key to work, the key contacts and side lever contacts should be examined for paper insulation, and the connections between the switchboard, transformer primaries, iron-core inductance, and keys should be examined. If the operator is sure that all the external connections of the circuit are right, and if he is unable to obtain a deflection of either the voltmeter or ammeter, he may give attention to the connections behind the switchboard. A galvanometer may be used to test all the internal connections of any part of this circuit in the manner already described.

H.T. and Closed Oscillating Circuits.—As there is no simple indication of the H.T. circuit being "O.K." in itself, it may be examined for faults together with the closed oscillating circuit. The size of the spark-gap in the latter should be first adjusted to the required width for the particular wave length required—namely, three or four millimetres for the 600 metre wave, and six or eight millimetres for the 300 metre wave. The transformer secondaries and the main condenser banks should then be placed in series or parallel as required, and the connections throughout the circuit should be examined. Care should be taken that the ebonite insulating strips between the copper strip connections of the closed circuit are in their correct positions, otherwise sparking will take place between them instead of at the spark-gap. After all external connections have been verified a spark should be

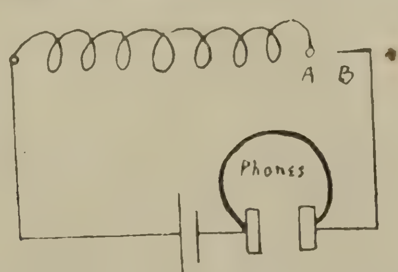


Fig. 161.—Test for Induction Coil Secondary.

obtained. Failing this the choke coils may be tested for continuity with a galvo and Q cell. As the resistance of the transformer secondaries is several thousand ohms, the dry cell and galvo are useless for testing it for continuity. The secondaries should be tested, therefore, by means of a cell and a pair of telephones joined in series across the terminals, as in Fig. 161. A hissing sound in the 'phones on making a rubbing contact between A and B denotes continuity. Absence of such hissing indicates some internal disconnection, which must be put right.

The main condenser may then be tested for a breakdown. The two banks should be tested separately, a good method being to connect the induction coil of the emergency gear across the terminals. If a small spark (one or two millimetres at the outside) be obtained at the discharge rods on depressing the key, the condenser is in a good condition. If a spark cannot be obtained, the faulty banks should be lifted out of the container by means of the cradles and allowed to drain. The induction-coil test may then be again applied, when a spark will be seen to take place inside the condenser through any broken glass plate which may exist. A broken or cracked glass plate may also be detected by placing a light at one end of the bank and looking through from the other end. When the position of a broken plate has been determined a new one may be inserted between the two zincs facing it, and by gently forcing the new plate forward the broken pieces of the old one will be found to give place readily, being pushed out at the opposite end of the bank. On no account should the bank be taken to pieces, as the rebuilding is a long and tedious operation. Of course, if a zinc plate is spoiled by a breaking of the lugs, the connecting bolts must be removed, and with a little care and patience a new one may be inserted. When the condensers and transformer are found to be intact no difficulty should be encountered in obtaining a spark.

The Radiating Circuit.—As this is such a simple series circuit, an examination of the connections is all that is necessary. The earth arrester may be examined to see that the two plates are not shorted by corrosion or any foreign matter, although a "short" would affect reception and not transmission. Tests for continuity in the jigger

secondary winding and aerial tuning inductance may be made by means of a dry cell and galvanometer, and, of course, the insulation of the aerial must be examined, as a direct earth would result in failure to set up oscillations

The Receiving Circuit.—Before attempting to receive signals it is necessary to wind up the clockwork of the magnetic detector. This clockwork is of a robust character and very seldom gets out of order. If the mainspring breaks it may be found rather difficult to repair it, and as a rule, if no other receiver is handy, it becomes necessary to turn the pulley by hand; or a fan motor may be adapted with a certain amount of ingenuity to drive the pulley.

The primary and secondary windings of the detector may be tested for continuity by means of a cell and galvo, and if a break is found the tuner connections may be transferred to the extra set of coils with which the instrument is provided. The broken coil may then be replaced by one of the spare ones invariably supplied to a station. In fitting a new primary it will be found necessary to cut away the thread binding one end of the winding to the glass tube over which it is wound in order to pass it through the small hole in the centre of the secondary bobbin. When the primary has been placed in position the loose end must be rebound with one or two turns of thread. If it be found necessary to fit a new moving band the two ends should be joined by means of No. 36 iron wire, a reel of which is supplied. The tension of the band should be adjusted so that it is held taut and moves at a constant speed. If no signals are heard in the telephones the following points should be attended to. First examine the 'phones. See that the diaphragms are properly fixed and that no paper has been placed between them and the magnets, thus jamming them and preventing proper working. See that no "short" is caused by the ends of the flexible leads being in contact with the metal parts of the head gear. A good method of testing the 'phone leads and magnet windings for continuity is as follows: Place one of the lugs on the end of the leads between the teeth and rub the other lug with a piece of iron—a tommy or key will serve. A hissing sound in the 'phones corresponding to the rubbing of the lug indi-

cates that the 'phones are in good order. The electro-magnets are affected by the small currents due to galvanic action set up by the body.

The micrometer spark-gap should then be examined to see that it is not screwed tight home. If the spark points are touching, a direct path to earth is afforded for the received currents. The earth arrester must also be examined for a short, as this would also afford a direct path to earth for the received currents.

Next see that the telephones are not shorted in any manner. A small piece of wire may have been connected across the short-circuiting contacts of the manipulating key, or the contacts themselves may be touching. Another piece may have been put across the condenser terminals, and still a third piece may have been connected across the detector terminals.

Follow out the connections from the two plates of the earth-arrester to the aerial and earth terminals of the multiple tuner, and see that the latter is properly connected to the primary of the detector. See that the 'phones, condenser, and short-circuiting contacts are properly connected to the secondary of the detector.

The various circuits of the tuner may be tested for continuity or short circuit by means of a dry cell and galvanometer. If a breakdown be discovered which cannot easily or conveniently be repaired, it may be found expedient to wind a small inductance coil. This may be

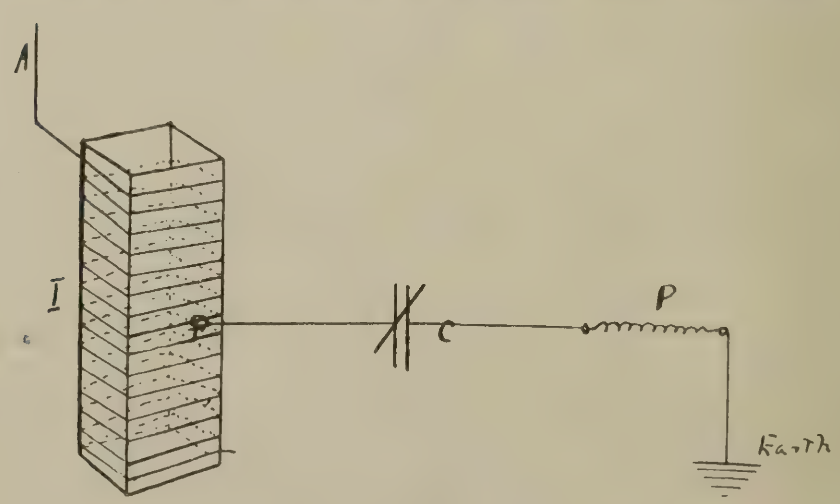


Fig. 162.—Improvised Receiving Circuit.

wound with No. 20 bare copper wire (a large reel of which is usually supplied) over a wooden former, which can be easily made by the ship's carpenter, if not by the operator himself. About 100 turns round a former of about 3 inches diameter will be found sufficient for most purposes. Care must be taken, of course, that adjacent turns of wire do not touch. This inductance may be connected to the aerial and detector as shown in Fig. 162. The aerial, A, is connected to one end of the improvised inductance, I. Connection may be made between one side of one of the tuner condensers, C, and the inductance by means of a short length of $2\frac{1}{2}$ ampère flex, to the other end of which a tie clip, T, has been soldered. The other side of the condenser is connected to earth through the primary, P, of the magnetic detector. To vary the inductance for tuning it is only necessary to alter the position of the clip, T.

The Emergency Gear.—The accumulator faults have already been discussed.

On depressing the manipulating key the hammer should begin to vibrate. Failing this, the connections between the switchboard, coil and key should be examined. The coil and key contacts should be examined to see that no paper has been inserted, and the coil contacts should be properly adjusted. The ends of the primary winding should be in good metallic connection with the terminals on the supporting pillars.

The connections behind the switchboard and in the base of the coil and key may be tested with the cell and galvo.

The discharge-rods must be connected to the secondary terminals of the coil by means of the small choke coils.

As has already been explained, the emergency set is worked with a plain aerial spark. In very wet or foggy weather it is found rather difficult to obtain a good spark on account of the insulation of the aerial breaking down. A small condenser inserted in the aerial helps to overcome this difficulty, although the spark produced does not give nearly such powerful results as the proper plain spark. Two of the main condenser spare zincs may be fixed on the opposite sides of a spare glass plate and held in position by means of rubber tape. One zinc should be

connected to the end of the aerial at the Bradfield insulator, and the other zinc to one of the coil discharge rods, the other rod being, as usual, connected to earth. The spark obtained will be found to be much longer than the ordinary plain spark but not nearly so fat, and it will not work so far. This device is only to be used in extreme cases. Alternatively, the coil secondary may also be connected to the main condenser of the $1\frac{1}{2}$ K.W. closed oscillating circuit, in which case, although only a very short low-frequency spark is obtainable, the arrangement is capable of effective transmission to a considerable distance.

The fuses on the marine switchboard may blow, and, of course, where this has occurred the fault is plainly seen. The fuse in the centre of the bottom edge of the board is for the protection of the coil when working from the accumulators, and the other two are in the main charging and working circuit. These fuses will blow at about 15 ampères.

Special Note.—In order that tests may be carried out rapidly and efficiently, it is absolutely necessary that the wiring diagrams of the various pieces of apparatus and the various circuits should be committed to memory.

As the galvanometer plays a very important part in the testing of the apparatus, care should be taken that it is in good condition itself. Operators under test have been known to discover faults in a circuit which never existed, merely because they failed to see that the galvo needle had been jammed into a fixed position.

The Buzzer Circuit.—The receiving circuit may be tested by means of the buzzer. This piece of apparatus is similar to an ordinary electric bell from which the gong and hammer have been removed. The connections are shown in Fig. 163. F is an iron frame on which two electro-magnets, M, are mounted. An armature, D, fixed to a spring, G, is attached to the frame and carries a contact, C, which is ordinarily at rest against an adjustable contact, C_1. The iron frame is connected to two terminals marked E and B, and the adjustable contact and one end of the magnet winding are connected to a terminal marked A, the other end of the magnet winding being connected to a terminal marked K.

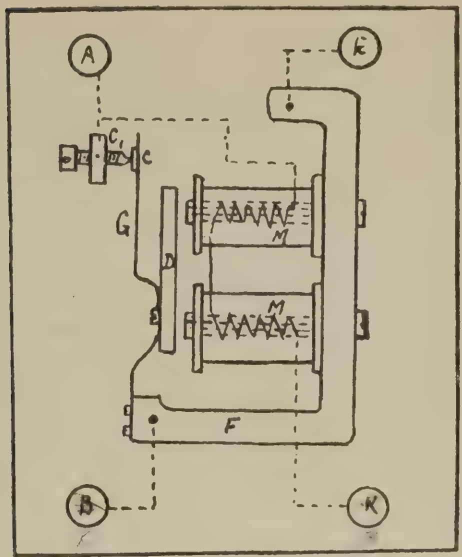


Fig. 163.—Sparking Buzzer.

If one or two cells be joined, through a small key, between the terminals B and K (battery and key), a depression of the key allows a current to pass through the coils. The armature, D, is attracted and the circuit is broken at C, the armature being immediately released. By this means an intermittent current is made to traverse the circuit, and a small spark is formed between the contact points. One of the contacts may be connected to a short aerial wire (two or three feet), attached to the terminal A, and the other may be connected to earth through the terminal E; the arrangement thus produced being a feeble plain-aerial transmitter capable of setting up oscillations in the receiving circuit if the latter be properly connected up.

An alternative arrangement of the buzzer circuit, and one which is more useful, is shown in Fig. 164. A slight modification of the buzzer itself is necessary in this case, this modification being the inclusion of the non-inductive resistance coil, S, between the terminal, B, and the back contact, C_1..

This resistance is, therefore, shunted across the buzzer electro-magnet windings, and a buzzer of this type is called a "shunted" or "tuned" buzzer, while the ordinary un-shunted buzzer is called a "sparking" buzzer.

The shunted buzzer, key and cells are connected up in series, one end of the series being connected to the earth terminal of the multiple tuner and the other end being connected to one side of the tuner aerial tuning con-

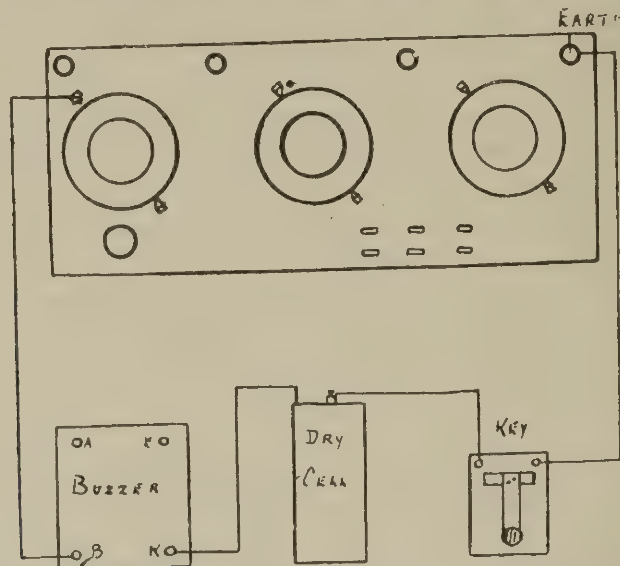


Fig. 164. – Shunted Buzzer Circuit Connections (External).

denser, as shown in Fig. 164. If the other terminal of this condenser be used it is impossible to pass a current through the circuit, as the condenser is not a conductor for D.C. current. The internal connections are shown in Fig. 165.

Excitation by Means of Shunted Buzzer.—Up to the present a condenser has been used as the means of storing up energy for the excitation of an oscillatory circuit. Energy may, however, be stored up or applied to the inductance of such a circuit.

When a current is sent through an inductance coil a magnetic field is set up round it which remains constant as long as the current remains constant. If the current be suddenly interrupted the energy of the magnetic field is transferred to the circuit, and if the inductance forms part of an oscillatory circuit oscillations are set up.

In Fig. 165 the circuit containing the inductance, I, the key, K, and the buzzer has an intermittent current flowing in it. The inductance of the buzzer electro-magnet windings ordinarily causes a spark to take place

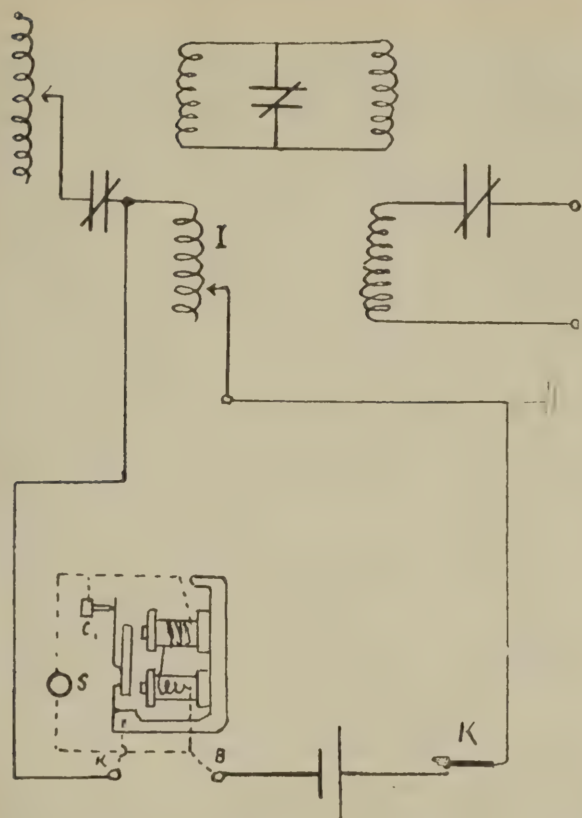


Fig. 165.—Shunted Buzzer Circuit Connections (Internal).

between the contacts, and thus the interruption of the current takes place more or less slowly. In the shunted buzzer the energy stored in the inductance of the magnet windings finds a path through the non-inductive resistance, S, and thus the sparking is eliminated, the current through I is interrupted extremely suddenly, and the energy stored in I sets up oscillations in the aerial circuit.

If, now, the intermediate condenser be set to a value for any particular wave length, the aerial and detector circuits may be adjusted until they are in tune. By altering the intermediate condenser values and by tuning the other two circuits to the altered adjustments, the tuner may be calibrated throughout for any particular aerial with which it is being used, and thus the different circuits may be placed in syntony for the reception of any particular wave when on the tuned side.

SPECIAL NOTES.—When the buzzer is connected up in the second manner, the production of signals in the telephones, when on the " stand bi " side, is not an indication

that everything is correct. It will be found that signals are produced even when the iron band is not rotating. The reason of this is that the inductance-charging current is passing directly through the primary of the detector and induces currents in the secondary, the two windings acting as a step-up transformer. This is, however, a good test for continuity of the windings.

When on the tuned side it will be found impossible to obtain a vibration of the buzzer armature if the tuning switch remains on the first stop. This is because the small block condenser inserted in series for the reception of very short waves is in series with the buzzer circuit, thus preventing the passage of the current. In order, therefore, to test or tune the three circuits the tuning switch must be placed on the second, third or fourth stop.

Use of Buzzer for Exciting Transmitting Circuits.—The transmitting circuits may be very easily tuned by means of the buzzer. The following figures show the connections for making various tests in which the multiple tuner is used as a wave-meter.

As already explained, a loop of wire must be joined across the aerial and earth terminals of the tuner, and it

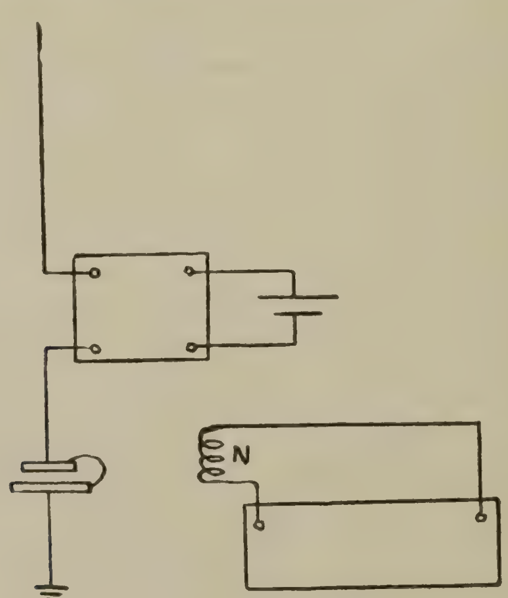


Fig. 166.—Excitation of Plain Aerial by means of Sparking Buzzer. N = 3 turns. Careful Buzzer adjustment is required. Good results may be obtained. Earth Arrester shorted.

will be seen that in some cases a greater number of turns is necessary than in others. The detector and telephones are used in connection with the multiple tuner as a means of detecting when a condition of resonance has been

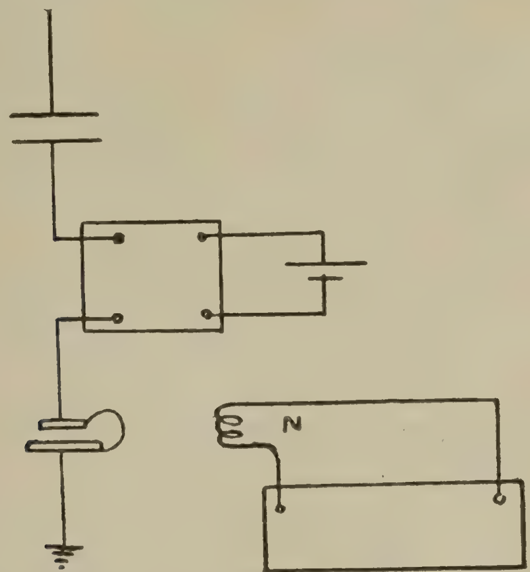


Fig. 167.—Excitation of Aerial with Condenser in series by means of Sparking Buzzer. N = 2 or 3 turns. Buzzer may be inserted above or below the Condenser. Arrester shorted. Good results may be obtained.

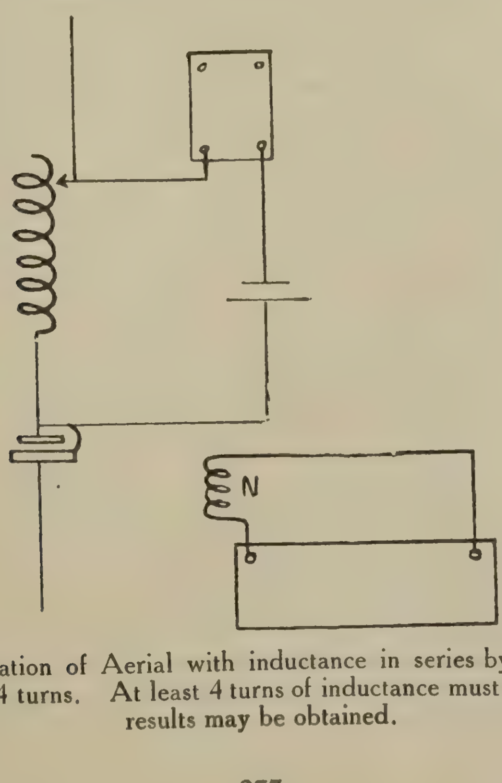


Fig. 168.—Excitation of Aerial with inductance in series by means of Shunted Buzzer. N = 14 turns. At least 4 turns of inductance must be buzzed. Good results may be obtained.

attained, but the connections are omitted in order to simplify the sketches.

Fig. 166 shows the method of exciting a plain aerial by means of the sparking buzzer. It is useful for determining the natural wave length of the aerial when required as an indication of the amount of additional inductance necessary for a certain wave length.

Fig. 167 shows the method of exciting an aerial in series with a condenser by means of a sparking buzzer. It is useful for determining the value of the extra condenser when tuning for a short wave.

Fig. 168 shows the method of exciting an aerial in series with inductance by means of a shunted buzzer. It is useful for tuning the radiating circuit.

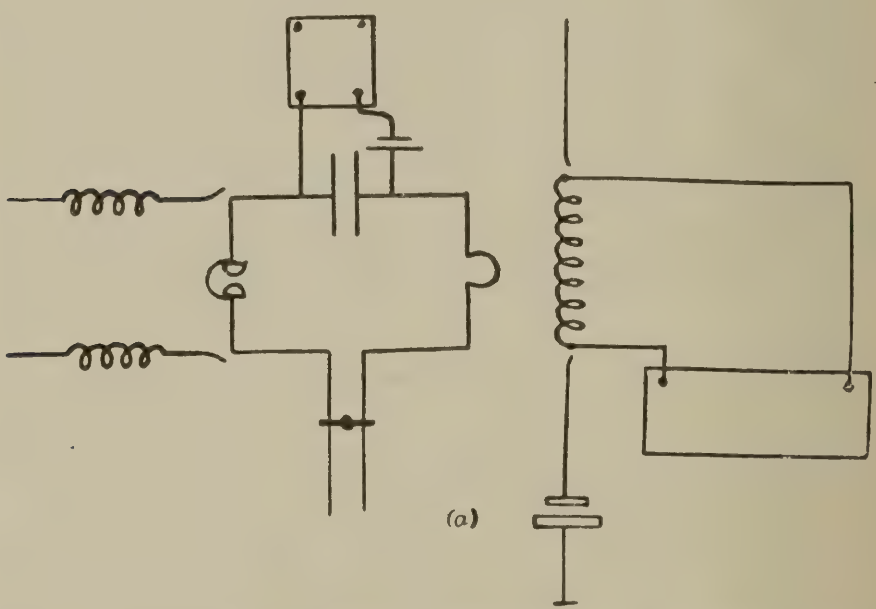


Fig. 169.—(*a*) Excitation of closed Oscillating Circuit by means of Shunted Buzzer. Spark-gap shorted. Transformer disconnected. Jigger secondary disconnected from Aerial and Earth and connected to Tuner. Coupling rather loose. Good results obtained.

Fig. 169 (a and b) shows the method of exciting the closed oscillating circuit by means of (a) a shunted buzzer, (b) a sparking buzzer. These methods are useful for tuning the closed circuit.

In the first two cases the sparking buzzer is used because the inductance energy with which a short length of

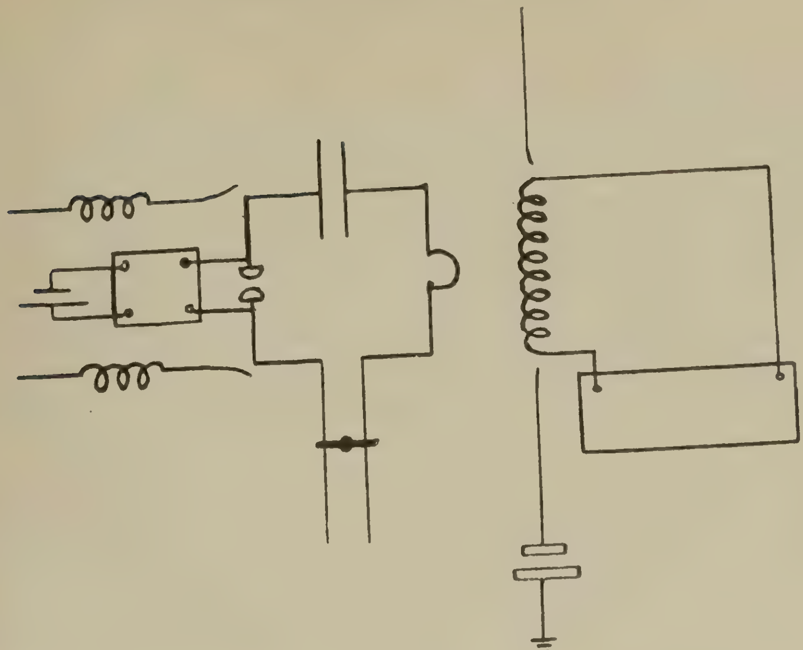


Fig. 169.—(*b*) Excitation of closed Oscillating Circuit by means of Sparking Buzzer. Good results obtained. Signals stronger than in (*a*). Length of leads to buzzer may cause inaccuracy by altering the inductance of the circuit.

straight wire can be charged is too small to produce detectable results.

As the shunted buzzer is of comparatively recent introduction, the great majority of ship installations are supplied with the ordinary sparking buzzer, but the latter may be modified in a very simple manner.

A resistance of from 5 to 10 ohms is a suitable value for the shunt for most buzzers. Failing other materials, 3 feet of the iron wire used for magnetic detector bands serves the purpose fairly well. It can be wound non-inductively on a match and tucked away under the magnet coils. In order that the resistance may be non-inductive the length of wire must be doubled on itself at its middle point and wound as shown in Fig. 170.

Multiple Tuner Faults.—It occasionally happens that, on account of having worked with too wide a micrometer

Fig. 170.—Improvised Shunt for Buzzer.

spark gap, the aerial tuning condenser of the multiple tuner breaks down. In such an eventuality the operator should not attempt to repair the condenser, as, on account of the delicate parts, he is more likely to cause more damage. It may be useful, however, to know how to replace the faulty condenser with either the intermediate or detector tuning condenser. This interchanging of condensers renders the "tune" side of the instrument useless, but the operator will be able to manage on the "stand bi" side until more efficient repairs can be made on reaching the home port.

Each condenser is fitted with two small black screws near the figure 5 on the scales. If the condenser be turned until the pointers indicate a reading of five divisions, and if these two screws be removed it will be found that the heads of two other small screws are revealed. By using a small screwdriver—it must be small enough to pass through the holes in the top of the condenser—the second pair of screws may be removed. If the large brass nut in the centre of the condenser handle be now removed, the whole condenser may be removed bodily from the rest of the instrument.

A Few Useful Hints.

Keep all parts of "Bradfield" leading-in insulator clean. The rod should be removed at least once a week and should be thoroughly cleaned from rust. Attention should be paid to the lock nuts, etc. If these little matters are not attended to the whole insulator may be ruined. The rod will be found to jamb and can only be removed by smashing the ebonite tube. The thread of the lock nuts may become so badly worn that it will be impossible to make a good electrical connection. If the whole insulator be dis-assembled about once a month, attention may be paid to the stuffing-box.

Spare "Bradfield" tubes should not be kept in a leaning position. They should be laid flat down on the deck or in a drawer, otherwise they are liable to bend, especially when in hot climates. It is difficult to pass the rod through a bent tube without breaking the latter.

All spare parts should be kept in a good condition. It is not advisable to keep such delicate spares as magnetic

primary windings amongst a number of heavy coach screws, tools, etc.

A little care might be exercised in the maintenance of the repair outfit, as repairs are much more easily carried out when good tools are available.

See that both sides of the magnetic detector are always ready for instant use.

Remove all fuses when in port, as this is an effective way of preventing unauthorised and incompetent people from working the gear should they obtain admission to the room in the operator's absence.

Keep all bare copper leads clean and bright. Do not try any such labour-saving devices as paint, enamel, etc.

Do not make the cabin look like a rag-shop or a nursery by sticking newspaper cuttings, etc., all over the bulkheads.

Do not spread oil indiscriminately over new instruments. It does not improve their appearance. A dry dusting brush or duster should be sufficient.

Do not be afraid of drawing attention to a leaking cabin. Nothing is so conducive to bad working as wet and dirty apparatus.

The discharger should be given careful attention. The occasional application of a duster will considerably prolong the life of the discharger. Renew the lime in the zinc tray occasionally, and above all keep the electrodes clean and smooth.

Keep the earth arresters clean—which does not imply any necessity to rub off the lacquer.

After a prolonged run be careful to see that no part of the apparatus has become unduly heated. Careful attention to this advice may prevent a serious fire taking place.

Use your nose as well as your eyes and ears to detect signs of burning or undue heating from leakage, bad connections, and so on. Never leave any such symptom unaccounted for or unremedied.

Never put in the main switch before ascertaining that the handle of the starter is on the "off" position.

When working with a strange or new set of apparatus, examine the high tension and oscillatory circuits before closing the switch of the Iolanda board.

Don't neglect your tuning-lamp as an indicator as to whether your apparatus is all in order.

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